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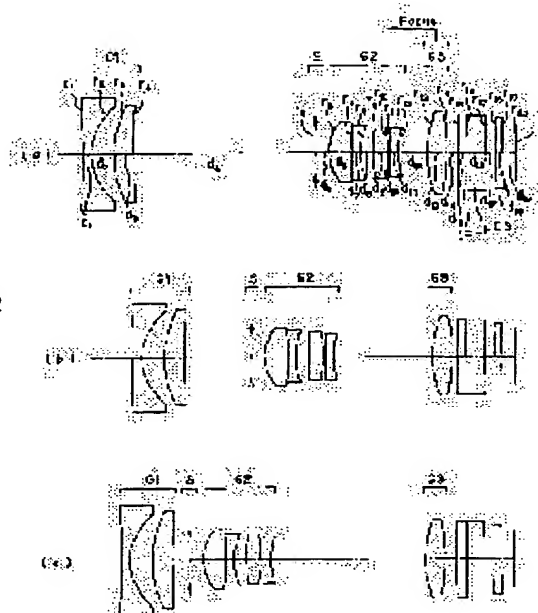
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(54) ZOOM LENS AND ELECTRONIC IMAGE PICKUP DEVICE HAVING THE SAME

(57)Abstract:

PROBLEM TO BE SOLVED: To make a video camera and a digital camera drastically thinner by using a zooming system which has a smaller number of lens pieces, can be easily made smaller and simpler and has high image formation performance.

SOLUTION: A zoom lens consists of a negative first group G1, an aperture diaphragm S, a positive second group G2, and a positive third group G3. In performing power variation from a wide angle end to a telephoto end, the second group G2 is moved only to an object side, and the third group G3 is moved while changing its interval with the second group G2. The second group G2 consists of a positive lens, a negative lens, a positive lens and a negative lens. At least either a positive lens or a negative lens of an image side in the second group G2 has an aspheric surface, and satisfies a condition (1) concerning the ratio of a radius of curvature on the optical axis of the surface of the object side of the positive lens of the object side of the second group G2 to that of the surface of an image side of the negative lens of the object side.



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CLAIMS

[Claim(s)]

[Claim 1] The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power, Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is the zoom lens characterized by for which lens having the aspheric surface and satisfying the following conditions (1) of the positive lens L23 in said 2nd lens group, or a negative lens L24 at least.

(1) $0.6 < R22R/R21F < 2.2$ however $R21F$, and $R22R$ It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of the negative lens L22 of the 2nd lens group, respectively.

[Claim 2] The claim 1 written zoom lens characterized by uniting with the electronic image sensor arranged on an image side.

[Claim 3] In the zoom lens arranged on the image pick-up side side of an electronic image sensor said zoom lens The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power, Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is the zoom lens characterized by for which lens having the aspheric surface and satisfying the following conditions (2) of the positive lens L23 in said 2nd lens group, or a negative lens L24, (3), and (4) at least.

(2) $0 < (C24F - C23R)$ and $L < 1.6$ (3) $0.01 < d23 / L < 0.2$ (4) It corrects $-0.4 < L/f2R < 0.8$. $C23R = 1/R23R$, and $C24F = 1/R24F$ it is --- here $R23R$ and $R24F$, respectively The field by the side of the image of the positive lens L23 of the 2nd lens group, The radius of curvature on the optical axis of the field by the side of the body of the negative lens L24 of the 2nd lens group and L The diagonal length of the effective image pick-up field (abbreviation rectangle) of an image sensor (mm). Optical-axis absentminded mind spacing of the positive lens L23 of the 2nd lens group and a negative lens L24 and $f2R$ of $d23$ are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[Claim 4] Electronic image pick-up equipment characterized by having the zoom lens of three given in any 1 term from claim 1.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the electronic image pick-up equipment or the zoom lenses which realized thin shape-ization of the depth direction by the device of optical-system parts, such as a zoom lens, especially, such as a video camera and a digital camera, about the electronic image pick-up equipment which has a zoom lens and it. Moreover, the zoom lens is related with the thing which made the rear focus become possible.

[0002]

[Description of the Prior Art] In recent years, the digital camera (electronic camera) has attracted attention as a next-generation camera which replaces 35mm film (common-name Leica version) camera of silver salt. Furthermore, it has many categories increasingly in the range where a business-use highly efficient type to a portable spread type is broad.

[0003] In this invention, it is aiming at offering the technique of realizing a video camera with thin depth, and a digital camera, securing high definition especially paying attention to a category portable spread type. it is the greatest neck making the depth direction of a camera thin -- optical system, especially a zoom lens system -- it is thickness most from the field by the side of a body to an image pick-up side. Recently, it is in use to adopt the so-called collapsible mount type lens-barrel which pushes out optical system out of a camera body at the time of photography, and contains optical system in a camera body at the time of carrying.

[0004] However, the thickness at the time of optical-system collapsing changes greatly with the lens types and filters to be used. Even if especially the so-called forward precedence mold zoom lens with which the lens group by the side of a body has forward refractive power most in order for a zoom ratio, an F value, etc. to set up a specification highly has large thickness and DEDDO tooth space of each lens element and they collapse it, thickness does not so much become thin (JP,11-258507,A). With a negative precedence mold, although especially the zoom lens of 2 thru/or 3 group configurations is advantageous in that respect, also when the lens by the side of a body is a positive lens most, even if there is much configuration number of sheets in a group, or the thickness of an element is large, or it collapses, it does not become thin (JP,11-52246,A). The image formation engine performance which was suitable for electronic image sensors while being known now, and includes a zoom ratio, a field angle, an F value, etc. is good, and although it has possibility that collapsing thickness can be made the thinnest, there are things, such as JP,11-287953,A, JP,2000-267009,A, and JP,2000-275520,A, as an example.

[0005] Although it is good to make an entrance pupil location shallow for making the 1st group thin, for that purpose, the scale factor of the 2nd group will be made high. It increases [it not only becomes difficult for the burden of one side, therefore the 2nd group to become large, and to make itself thin, but / effectiveness of the difficulty of aberration amendment or a manufacture error] and is not desirable. Although what is necessary is just to make an image sensor small in order to carry out thin-shape-izing and a miniaturization, in order to consider as the same number of pixels, it is necessary to make a pixel pitch small, and the lack of sensibility must be covered by optical system. The effect of diffraction is also ****.

[0006] Moreover, in order to make it a camera body with thin depth, it is effective on the layout of a drive system to perform lens migration at the time of a focus not in a pre-group but in the so-called rear focus. Then, the need that the aberration fluctuation when carrying out a rear focus chooses little optical system comes out.

[0007]

[Problem(s) to be Solved by the Invention] This invention is made in view of such a situation of the conventional technique. The purpose There is little configuration number of sheets and it is easy to make it simple by device layout top small, such as a rear focus method. The zoom method or zoom configuration which has the high image formation engine performance stabilized from the infinite distance to the short distance is chosen. Further It is making each lens element of a zoom lens thin, and attaining thorough thin shape-ization of a video camera or a digital camera also in consideration of selection of filters in making total thickness of each group thin ****.

[0008]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, the zoom lens of this invention The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power, Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is characterized by for which lens having the aspheric surface and satisfying the following conditions (1) of the positive lens L23 in said 2nd lens group, or a negative lens L24 at least.

[0009]

(1) $0.6 < R22R/R21F < 2.2$ however R21F, and R22R It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of the negative lens L22 of the 2nd lens group, respectively.

[0010] In this case, it is desirable to unite with the electronic image sensor arranged on an image side.

[0011] In the zoom lens with which the zoom lens of this invention is arranged on the image pick-up side side of an electronic image sensor moreover, said zoom lens The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power, Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with

the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is characterized by for which lens having the aspheric surface and satisfying the following conditions (2) of the positive lens L23 in said 2nd lens group, or a negative lens L24, (3), and (4) at least.

[0012]

(2) $0 < (C24F - C23R) \text{ and } L < 1.6$ (3) $0.01 < d23 / L < 0.2$ (4) It corrects $-0.4 < L/f2R < 0.8$, $C23R = 1/R23R$, and $C24F = 1/R24F$ it is -- here R23R and R24F, respectively The field by the side of the image of the positive lens L23 of the 2nd lens group, The radius of curvature on the optical axis of the field by the side of the body of the negative lens L24 of the 2nd lens group and L The diagonal length of the effective image pick-up field (abbreviation rectangle) of an image sensor (mm), Optical-axis absentminded mind spacing of the positive lens L23 of the 2nd lens group and a negative lens L24 and f2R of d23 are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0013] This invention contains electronic image pick-up equipment equipped with these zoom lenses.

[0014] Hereafter, the reason and operation which take the above-mentioned configuration in this invention are explained.

[0015] The 1st lens group which has negative refractive power in order [side / body] in this invention, It consists of the 2nd lens group which has forward refractive power, and the 3rd lens group which has forward refractive power. The variable power from a wide angle edge to a tele edge at the time of an infinite distance object point focus The monotonous migration by the side of the body of the 2nd lens group, In the zoom lens performed by migration of a different amount from the 2nd lens group of the 3rd lens group, the 2nd lens group has adopted the zoom lens constituted from the positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24 sequentially from a body side.

[0016] In addition, in this invention, the lens which consists of a medium with a single lens is made into one unit, and a cemented lens means what consists of two or more lenses.

[0017] in 2 group zoom of **** often used as a zoom lens for silver salt film cameras for many years, although it is good to make high the scale factor of the forward back group (the 2nd lens group) in each focal distance since it is miniaturized therefore One positive lens is added to the pan of the 2nd lens group as the 3rd lens group at an image side, and in case variable power is carried out to a tele edge from a wide angle edge, the method of changing spacing with the 2nd lens group is learned well. Moreover, this 3rd lens group has possibility that it can be used also as an object for focuses. and achievement of the purpose of this invention, i.e., the lens section total thickness at the time of collapsing receipt, -- thin -- carrying out -- in addition -- and in case a focus is carried out by the 3rd lens group, in order to control fluctuation of the aberration outside a shaft including astigmatism, sequentially from a body side, it is indispensable requirements to add and constitute a positive lens at least in a positive lens, a negative lens, and this, and the 2nd lens group is good to add a negative lens to an image side further.

[0018] The balance collapses and is not desirable, if the astigmatism which remains by the 1st lens group and the 2nd lens group in order to take out the effectiveness if the aspheric surface of the amount beyond the need goes into the 3rd lens group will be amended by the 3rd lens group and the 3rd lens group moves here for a focus, although aberration fluctuation becomes a problem when carrying out a focus by the 3rd lens group. Therefore, when carrying out a focus by the 3rd lens group, it must continue throughout a zoom and astigmatism must be cut with the 1st lens group and the 2nd lens group abbreviation picking. Therefore, the 3rd lens group is constituted from a spherical-surface system or a small amount of aspheric surfaces, an aperture diaphragm is allotted to the body side of the 2nd lens group, and the 2nd lens group is good to constitute in order of a positive lens, a negative lens, a positive lens, and a negative lens. Moreover, since a front ball diameter cannot become large easily by this type, it is hard to generate the dead space at the time of collapsing it is not only simpler on a device to make an aperture diaphragm into the 2nd lens group and one (for it to arrange in the example of after-mentioned this invention just before the 2nd lens group, and for them to be the 2nd lens group and one), but, and the F value difference of a wide angle edge and a tele edge is small. Moreover, it is better to make these a cemented lens, since generating of the aberration according [the positive lens and negative lens by the side of the body of the 2nd lens group] to those relative eccentricity is remarkable. When making it junction, it is good to cancel aberration as much as possible within a cemented lens (a positive lens L21, negative lens L22), and to make eccentric sensitivity small.

[0019] Then, it is good to satisfy the following conditional expression about the positive lens 21 of the 2nd lens group, and a negative lens L22.

[0020]

(1) $0.6 < R22R/R21F < 2.2$ however R21F, and R22R It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of the negative lens L22 of the 2nd lens group, respectively.

[0021] Although it is advantageous to amendment of the spherical aberration, the comatic aberration, and the astigmatism of whole system aberration if 2.2 of the upper limit of conditions (1) is exceeded, there is little effectiveness of relaxation of the eccentric sensitivity by junction. If 0.6 of a minimum is exceeded, amendment of the spherical aberration, the comatic aberration, and the astigmatism of whole system aberration will tend to become difficult.

[0022] In addition, it is more good to make it be the following.

[0023]

(1-1) It is best for $1.0 < R22R/R21F < 2.0$ pan to make it be the following.

[0024]

(1-2) It is good to be satisfied with $1.4 < R22R/R21F < 1.8$ pan of the following conditional expression about the positive lens L23 and negative lens L24 of the 2nd lens group.

[0025]

(2) $0 < (C24F - C23R) \text{ and } L < 1.6$ (3) $0.01 < d23 / L < 0.2$ (4) It corrects $-0.4 < L/f2R < 0.8$, $C23R = 1/R23R$, and $C24F = 1/R24F$ it is -- here R23R and R24F, respectively The field by the side of the image of the positive lens L23 of the 2nd lens group, The radius of curvature on the optical axis of the field by the side of the body of the negative lens L24 of the 2nd lens group and L The diagonal length of the effective image pick-up field (abbreviation rectangle) of an image sensor (mm), Optical-axis absentminded mind spacing of the positive lens L23 of the 2nd lens group and a negative lens L24 and f2R of d23 are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0026] If 0 of the lower limit of conditions (2) is exceeded, it will be easy to generate spherical aberration, and if 1.6 of a upper limit is exceeded, astigmatism cannot be amended even if it introduces the aspheric surface into the 1st lens group.

[0027] It aims at using effectively because of aberration amendment of the configuration of a field where both adjoin, without joining the positive lens L23 and negative lens L24 of the 2nd lens group in this invention. If 0.01 of the lower limit of conditions (3) is exceeded, field interference of a positive lens L23 and a negative lens L24 will tend to reach even in an effective diameter. If 0.2 of a upper limit is exceeded, the diameter of a lens will tend to become thick.

[0028] It is better to have made it become a forward value in that case, in order to make it more convenient [to concentrate eccentric sensitivity on a positive lens L21 and a negative lens L22], when an exit pupil location will approach the image

surface, and will tend to cause shading and it will consider a positive lens L21 and a negative lens L22 as junction, if -0.4 of the lower limit of conditions (4) is exceeded, when it could do. If 0.8 of an upper limit is exceeded, it will be hard to secure a small and high zoom ratio.

[0029] In addition, it is more good to make either or the plurality of condition (2) - (4) be the following.

[0030]

(2) ' $0.15 < (C24F - C23R)$ and $L < 1.3$ (3) ' $0.01 < d23 / L < 0.15$ (4) ' It is still better for $-0.3 < L/f2R < 0.5$ pan to make either or the plurality of condition (2) - (4) be the following. It is best to make especially all be the following.

[0031]

(2) -- " $0.3 < (C24F - C23R)$ and $L < 1(3)'' d23 / 0.01 < L < 0.1(4)'' -0.2 < L/f2R < 0.2$ -- again The aspheric lens for aberration amendment is good for the 1st lens group one sheet and to consider in the 2nd lens group as a total of three sheets in the whole system of two sheets for spherical aberration because of distortion aberration, astigmatism, and comatic-aberration amendment. Even if it puts in more than it, there is little effectiveness and it only becomes cost quantity.

[0032] Moreover, it is good about axial overtone aberration or chromatic-aberration-of-magnification amendment to fulfill the following conditions.

[0033]

(5) $25 < nu21 - nu22 + nu23 - nu24 < 55$, however $nu21$, $nu22$, $nu23$ and $nu24$ are the Abbe numbers (d line standard) of the medium of the positive lens L21 of the 2nd lens group, a negative lens L22, a positive lens L23, and a negative lens L24, respectively.

[0034] If the lower limit 25 of conditions (5) is exceeded, axial overtone aberration and the chromatic aberration of magnification will tend to become the lack of amendment, and these will tend to become overamendment if 55 of an upper limit is exceeded.

[0035] In addition, it is more good to make it be the following.

[0036]

(5) ' It is best for $25 < nu21 - nu22 + nu23 - nu24 < 50$ pan to make it be the following.

[0037]

(5) " It is good to satisfy the following conditions about the aspheric surface of $30 < nu21 - nu22 + nu23 - nu24 < 50$ next the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0038]

(6) 7.5×10^{-3} and $L > |Asp2R| > |Asp21F|$ -- however $Asp21F$ and $Asp2R$, respectively The field by the side of the body of a positive lens L21, As opposed to the spherical surface which has the radius of curvature on the optical axis of the field of a positive lens L23 or a negative lens L24 The height from an optical axis is the diagonal length (mm) of the effective image pick-up field (abbreviation rectangle) of an image sensor, and the amount of aspheric surface deflections in $0.3L$ and L set amount Asp of aspheric surface deflections 21F to 0, when the body side face of a positive lens L21 is the spherical surface.

[0039] That is, as the amount of aspheric surface deflections as used in the field of this invention is shown in drawing 13, when setting the diagonal length of the effective image pick-up field of an electronic image sensor to L to the spherical surface (criteria spherical surface) which has the radius of curvature r on the optical axis of the target aspheric surface, the height from an optical axis says the amount of deflections of the aspheric surface in the location of $0.3L$.

[0040] Like conditions (6), unless it introduces a certain amount of aspheric surface into a positive lens L23 or a negative lens L24, spherical aberration, comatic aberration, and astigmatism cannot fully amend. If there is whenever [less / aspheric surface] than a positive lens L21, amending [of comatic aberration and astigmatism] will be easy to become inadequate. It becomes [the eccentric sensitivity of a positive lens L23 or a negative lens L24 becomes large too much, and / components precision or assembly precision] severe and is not desirable if 7.5×10^{-3} and L of the upper limit are exceeded. In addition, the spherical surface is sufficient as the field by the side of the body of a positive lens L21.

[0041] In addition, it is more good to make it be the following.

[0042]

(6) ' 5.0×10^{-3} and $L >$ It is best for a $|Asp2R| > |Asp21F|$ pan to make it be the following.

[0043]

(6) -- " 2.5×10^{-3} and $L > |Asp2R| > |Asp21F|$ -- it is more good as another conditions to fill the following.

[0044]

(6-2) It is best for $|Asp2R| > 3$ and a $|Asp21F|$ pan to make it be the following.

[0045]

(6-3) When the following conditions are further satisfied to a $|Asp2R| > 6$, $|Asp21F|$, and conditions (2) system, the amendment top of spherical aberration is good.

[0046]

(7) $-0.5 < (R21F - R22R) / (R21F + R22R) < 0.3$ however $R21F$, and $R22R$ It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of a negative lens L22, respectively. Incidentally, this conditional expression has the inverse number of the usual shape factor.

[0047] If -0.5 of the minimum of this condition is exceeded, it will be easy to become the lack of spherical-aberration amendment, and lens thickness will tend to become thick. Moreover, the workability of the body side positive lens L21 also gets worse. If 0.3 of an upper limit is exceeded, conversely high order spherical aberration will occur, or the workability of the deep concave surface by the side of a negative lens will get worse.

[0048] In addition, it is more good to make it be the following.

[0049]

(7) -- ' $-0.4 < (R21F - R22R) / (R21F + R22R) < 0.2$ -- it is still better to make it be the following.

[0050]

(7) -- " $-0.3 < (R21F - R22R) / (R21F + R22R) < 0.1$ -- again -- a condition (2) system or (7) systems -- receiving -- the conditions of further the following -- any of (8) and (9) -- or if both are satisfied, it is advantageous about an exit pupil location, i.e., shading.

[0051] (8) $-1 < f3/f2R < 1.6$ (9) It corrects $0.02 < d22/L < 0.5$. $f2R$ and $f3$, respectively The synthetic focal distance of the positive lens L23 of the 2nd lens group, and a negative lens L24, and the focal distance of the 3rd lens group, $d22$ is spacing of the image side face of the negative lens L22 of the 2nd lens group, and the body side face of a positive lens L23, and L is the diagonal length (mm) of the effective image pick-up field (abbreviation rectangle) of an image sensor.

[0052] Although it is advantageous to the exit pupil location, i.e., shading, in a wide angle edge if 1.6 of the upper limit of conditions (8) is exceeded, the amount of fluctuation of the exit pupil location at the time of carrying out variable power to a tele edge is large, and becomes disadvantageous for shading in a tele edge. When -1 of a lower limit is exceeded, in case a focus is carried out by the point and the 3rd lens group which the exit pupil in a wide angle edge is too near, and shading

tends to generate, the movement magnitude becomes large too much, and there is disadvantage on a tooth space. Moreover, since it is necessary to strengthen the positive lens by the side of the image of the high 2nd lens group of the axial Uemitsu line quantity in paraxial, the principal point location of the 2nd lens group moves back, it is difficult to get and the 1st lens group tends to grow a high scale factor large.

[0053] If 0.02 of the minimum of conditions (9) is exceeded, it will be easy to generate shading influenced by amendment of astigmatism, and the exit pupil location in a wide angle edge. If 0.5 of an upper limit is exceeded, the thickness of the 2nd lens group will be thick and will serve as fetters making [of collapsing thickness] it small.

[0054] In addition, the 2nd The effectiveness to the performance degradation of a relative-position error with the subgroup which put together the subgroup and positive lens L23 which put together the positive lens L21 and negative lens L22 of a lens group, and the negative lens L24 [small] (However, as for the amount of aspheric surfaces of a positive lens L23, it is desirable to make it more smallish in that case.) You may make it the structure which prepares fixed spacing or changing spacing more greatly at the time of variable power and an image pick-up, and is contracted by that only at the time of collapsing. It is advantageous to engine-performance reservation of a periphery to enlarge d22 slightly at the time of an image pick-up.

[0055] In addition, it is more good to make it be the following in both conditions (8) and (9). [both / either or]

[0056]

(8) ' $-0.7 < f_3/f_2R < 1.0$ (9) $0.04 < d_{22}$ It is still better for $/L < 0.4$ pan to make it be the following in both conditions (8) and (9).

[both / either or] It is best to make especially both be the following.

[0057]

(8) " $-0.4 < f_3/f_2R < 0.4$ (9) " $0.06 < d_{22}$ If the following conditions are independently satisfied further to conditions (2) or (5) as be fastidious $/L < 0.3$, it is advantageous to the miniaturization at the time of collapsing.

[0058] (10) $-1 < f_2 F/R_{21R} < 2.5$, however R_{21R} The radius of curvature of the field by the side of the image of the positive lens L21 of the 2nd lens group and f_2F are the synthetic focal distances of the positive lens L21 of the 2nd lens group, and a negative lens L22.

[0059] Although it will be easy to make thin total thickness of the positive lens L21 and negative lens L22 of the 2nd lens group if 2.5 of the upper limit of conditions (10) is exceeded, amendment of axial overtone aberration becomes difficult.

Although it is advantageous to amendment of axial overtone aberration if -1 of a lower limit is exceeded, a thick kink colander is not obtained for the total thickness of the positive lens L21 and negative lens L22 of the 2nd lens group, but it becomes fetters making collapsing thickness thin.

[0060] In addition, it is more good to make it be the following.

[0061]

(10) ' It is best for $-0.8 < f_2 F/R_{21R} < 0.8$ pan to make it be the following.

[0062]

(10) " If the following conditions are further satisfied to $-0.6 < f_2 F/R_{21R} < \text{said } 0.5$ condition (2) system, (7) system, or (10) system, it is advantageous to the miniaturization at the time of collapsing.

[0063] (11) $-0.5 < f_2/f_2R < 1$, however f_2 The synthetic focal distance of the whole 2nd lens group and f_2R are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0064] Conditions (11) specify the ratio of the synthetic focal distance of the positive lens L23 of the 2nd lens group, and a negative lens L24, and the synthetic focal distance of the whole 2nd lens group. If 1 of an upper limit is exceeded, it will grow [whether mirror frame machine structure becomes complicated and] large, in order do not become high, but the movement magnitude of the 1st lens group becomes large, are easy to enlarge the 2nd lens group scale factor, or dead space tends to be made in the 2nd lens group back in a busy condition, since the principal point of the 2nd lens group becomes image side approach, and for an overall length to become long and to make collapsing thickness thin. Or it cannot do not much thinly. Amendment of astigmatism will become difficult if -0.5 of a lower limit is exceeded.

[0065] In addition, it is more good to make it be the following.

[0066]

(11) ' It is best for $-0.4 < f_2 / f_2R < 0.7$ pan to make it be the following.

[0067]

(11) " About $-0.3 < f_2/f_2R < 0.4$ and the 3rd lens group, although it is good to constitute from all the lens ***** spherical surfaces, it is good in that case to fulfill the following conditions geometrically.

[0068]

(12) R_{32} is the body side and the radius of curvature which is the field by the side of an image most of the positive lens of the 3rd lens group most as $-1.0 < (R_{31}+R_{32})/(R_{31}-R_{32}) < 1.2$, however R_{31} , respectively.

[0069] If 1.2 of the upper limit of conditions (12) is exceeded, even if fluctuation of the astigmatism by the rear focus becomes large too much and can amend astigmatism good in the infinity object point, astigmatism will tend to get worse to the short-distance object point. Although there is little astigmatism fluctuation by the rear focus when -1.0 of a lower limit is exceeded, the aberration amendment to the infinity object point becomes difficult.

[0070] In addition, it is more good to make it be the following.

[0071]

(12) -- ' $-0.3 < (R_{31}+R_{32})/(R_{31}-R_{32}) < 1.2$ -- it is still better to make it be the following.

[0072]

(12) " Although collapsing thickness was made thin about more than $0.0 < (R_{31}+R_{32})/(R_{31}-R_{32}) < 1.0$ and the zoom lens section, the means which makes the image formation engine performance good was offered.

[0073] In addition, the zoom lens of this invention is advantageous when electronic image pick-up equipment including a wide angle region is constituted. Half-field angle [of the direction of a vertical angle especially in a wide angle edge] ωW It is desirable to use for the electronic image pick-up equipment with which are satisfied of the following conditions (a wide angle edge half field angle given in each after-mentioned example is equivalent to ωW).

[0074] Although an aberration amendment top will become advantageous if a wide angle edge half field angle becomes narrow exceeding 27 degrees of the lower limit of this condition $W < 42$ degrees of 27 degrees $< \omega$, it is no longer a field angle in a practical wide angle edge. On the other hand, if 42 degrees of an upper limit are exceeded, it will become easy to generate distortion aberration and the chromatic aberration of a scale factor, and lens number of sheets will increase.

[0075] Next, reference is made about the affair which makes filters thin. The infrared-absorption filter which usually has fixed thickness in electronic image pick-up equipment so that infrared light may not carry out incidence to an image pick-up side is inserted in a body side rather than the image sensor. It considers transposing this to thin coating. Although it is the translation which becomes naturally that much thin, there is a secondary effect. Rather than the image sensor in zoom lens system back, to a body side, 80% or more, if the permeability (τ_{700}) in 700nm introduces 8% or less of near-infrared Sharp

cut coat, permeability (τ_{600}) with a wavelength of 600nm. The permeability of a near infrared region 700nm or more is lower than an absorption type. The permeability by the side of red becomes high relatively, the Magenta-ized inclination by the side of the purple-blue which is the fault of solid state image sensors, such as CCD which has a complementary color mosaic filter, is eased by the gain adjustment, and the color reproduction of the solid state image sensor averages, such as CCD which has a primary color filter, can be obtained.

[0076] Namely, (13) $\tau_{600}/\tau_{550} \geq 0.8$ (14) It is desirable to fill $\tau_{700}/\tau_{550} \leq 0.08$. However, τ_{550} is permeability with a wavelength of 550nm.

[0077] In addition, it is more good to make it be the following in both conditions (13) and (14). [both / either or]

[0078] (13) ' $\tau_{600}/\tau_{550} \geq 0.85$ (14) ' It is still better for $\tau_{700} / \tau_{550} \leq 0.05$ pan to make it be the following in both conditions (13) and (14). [both / either or] It is best to make especially both be the following.

[0079] (13) " $\tau_{600}/\tau_{550} \geq 0.9$ (14) " Another fault of solid state image sensors, such as $\tau_{700} / \tau_{550} \leq 0.03$ CCD, is that the sensibility to the wavelength of 550nm of a near-ultraviolet region is quite higher than that of human being's eye. This is also highlighting the color blot of the edge section of the image by the chromatic aberration of a near-ultraviolet region. It is fatal if especially optical system is miniaturized. Therefore, the ratio to 550nm it (τ_{550}) of permeability (τ_{400}) with a wavelength of 400nm is less than 0.08. If an absorber or a reflector to which the ratio to 550nm it (τ_{550}) with a permeability (τ_{440}) of 440nm exceeds 0.4 is inserted on an optical path, a required wavelength region will not be lost on color reproduction (have maintained good color reproduction), but noises, such as a color blot, will be mitigated considerably.

[0080] Namely, (15) $\tau_{400}/\tau_{550} \leq 0.08$ (16) It is desirable to fill $\tau_{440}/\tau_{550} \geq 0.4$.

[0081] In addition, it is more good to make it be the following in both conditions (15) and (16). [both / either or]

[0082] (15) ' $\tau_{400}/\tau_{550} \leq 0.06$ (16) ' It is still better for $\tau_{440} / \tau_{550} \geq 0.5$ pan to make it be the following in both conditions (15) and (16). [both / either or] It is best to make especially both be the following.

[0083] (15) " $\tau_{400}/\tau_{550} \leq 0.04$ (16) " As for $\tau_{440}/\tau_{550} \geq 0.6$, in addition the installation of these filters, between image formation optical system and image sensors is good.

[0084] On the other hand, in the case of a complementary filter, the merit when using small CCD from the height of the transmitted light energy, since substantial sensibility is high and advantageous also in resolving compared with CCD with a primary color filter is size. Also about the optical low pass filter which is another filter, it is the total thickness tLPF. (mm) is good to fulfill the following conditions.

[0085]

(17) $0.15 < tLPF / a < 0.45$, however a are the level pixel pitches (unit μm) of an image sensor, and are 5 micrometers or less.

[0086] Although it is also effective to make an optical low pass filter thin in order to make collapsing thickness thin, generally moire depressor effect decreases and is not desirable. On the other hand, the contrast of the frequency component beyond a nyquist limitation decreases, and the phenomenon of moire depressor effect comes to be permitted to some extent by the effect of the diffraction of an image formation lens system as a pixel pitch becomes small. For example, when whenever [azimuth / at the time of projection on the image surface] uses in piles three kinds of filters which have a crystallographic axis in a horizontal (= 0 degree) and the direction of ± 45 degree, respectively in the direction of an optical axis, it is known that there is moire depressor effect considerably. As a specification to which the filter in this case becomes the thinnest, what can shift only $\text{SQRT}(1/2) * a \mu\text{m}$ in amum and the direction of ± 45 degree horizontally, respectively is known. The filter thickness at this time is about set to $[1 + 2 * \text{SQRT}(1/2)] * a / 5.88$ (mm). Here, SQRT is the square root and means a square root. This is a specification which makes contrast zero in the frequency which is equivalent to a nyquist limitation exactly. Although the contrast of several % thru/or the frequency equivalent to a nyquist limitation will come out for a while rather than this if it is made thin about dozens of%, ***** stopped under the effect of the above-mentioned diffraction becomes possible.

[0087] Also when carrying out by filter specifications other than the above, for example, a two-sheet pile, and one sheet, it is good to satisfy [include] conditions (17). If 0.45 of the upper limit is exceeded, an optical low pass filter will be too thick, and will become the hindrance of thin-shape-izing. Moire removal will become inadequate if 0.15 of a lower limit is exceeded. However, the conditions of a in the case of carrying this out are 5 micrometers or less.

[0088] If a is 4 micrometers or less, since it is easier to be influenced of diffraction, it is (17)'. It is good also as $0.13 < tLPF / a < 0.42$.

[0089] Moreover, you may make it be the following according to the number of sheets of a level pixel pitch and the low pass filter to pile up.

[0090] (17) " At $0.3 < tLPF / a < 0.4$ however a three-sheet pile, and the time of $4 \leq a < 5$ (micrometer) At $0.2 < tLPF / a < 0.28$ however a two-sheet pile, and the time of $4 \leq a < 5$ (micrometer) $0.1 < tLPF / a < 0.16$, however one sheet At and the time of $4 \leq a < 5$ (micrometer) It is $0.08 < tLPF / a < 0.14$, however one sheet at the time of $a < 4$ (micrometer) at $0.16 < tLPF / a < 0.25$ however a two-sheet pile, and the time of $a < 4$ (micrometer) at $0.25 < tLPF / a < 0.37$ however a three-sheet pile, and the time of $a < 4$ (micrometer).

[0091] When using an electronic image sensor with a small pixel pitch, image quality deteriorates under the effect of the diffraction effect by narrowing down. It can insert most into which [between the lens sides by the side of a body] optical path. therefore, two or more openings of immobilization of opening size -- having -- one of them -- the 1st lens group -- most -- the lens side by the side of an image, and the 3rd lens group -- And it considers as the electronic image pick-up equipment which can adjust an image surface illuminance by supposing that it is exchangeable with other openings. It is good to perform quantity of light accommodation, as the permeability to 550nm differs in a part of openings in two or more of the openings, respectively and it has a medium which is less than 80%. Or when adjusting so that it may become the quantity of light equivalent to an F value which is set to a (micrometer) / f number < 0.4 , it is good to consider as the electronic image pick-up equipment which the permeability to 550nm differs in opening, respectively, and has less than 80% of medium. For example, from the open value, if out of range, he has no medium or the permeability to 550nm which is the above-mentioned conditions considers as 91% or more of dummy medium, and it is [like / the diameter of an aperture diaphragm is not made small, so that the effect of diffraction comes out, and / an ND filter] good at the time of within the limits to carry out quantity of light accommodation.

[0092] Moreover, what puts in in opening the optical low pass filter with which a path is made into what was made small in inverse proportion to the F value, two or more of the openings are arranged, respectively, and frequency characteristics differ instead of an ND filter, respectively is sufficient. Since diffraction degradation becomes large as it narrows down, the frequency characteristics of an optical low pass filter are highly set up, so that the diameter of opening becomes small.

[0093]

[Embodiment of the Invention] Hereafter, the examples 1-10 of the zoom lens used for the electronic image pick-up equipment of this invention are explained. The wide angle edge at the time of the infinite distance object point focus of

examples 1-10 (a), an intermediate state (b), and the lens sectional view in a tele edge (c) are shown in drawing 1 - drawing 10, respectively. I has shown the image surface of CG and CCD for the cover glass of CCD IF and whose low pass filter of G3 and an infrared cut absorption filter G2 and the 3rd lens group are [the 1st lens group / G1 and a diaphragm] LF and an electronic image sensor for S and the 2nd lens group among each drawing. In addition, it may replace with infrared cut absorption filter IF, what was used as the near-infrared Sharp cut coat at the plane of incidence of a transparence plate may be used, and a direct near-infrared Sharp cut coat may be given to a low pass filter LF.

[0094] The 1st lens group G1 of negative refractive power, aperture-diaphragm S, both the convex positive lens, and the cemented lens of both the concave negative lens which are from the positive meniscus lens of a convex on a both concave negative lens and body side as the zoom lens of an example 1 is shown in drawing 1. It consists of 3rd lens group G3 of the forward refractive power which consists of both convex positive lens, and the 2nd lens group G2 of the forward refractive power which is from the negative meniscus lens of a convex on a body side and both one convex positive lens. In case variable power is carried out to a tele edge from a wide angle edge, the 1st lens group G1 draws the locus of concave, and moves to a body side. Becoming a location by the side of the image surface from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 draws the locus of a convex, and moves to an image surface side, and it becomes a location by the side of a body from a wide angle edge by the tele edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0095] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0096] As the zoom lens of an example 2 is shown in drawing 2, at a positive meniscus lens [of a convex], and body side to a 1st lens group [of the negative refractive power which consists of both concave negative lens and both convex positive lens] G1, aperture-diaphragm S, and body side The cemented lens of the negative meniscus lens of a convex, In case it consists of 3rd lens group G3 of the forward refractive power which consists of the 2nd lens group G2 of the forward refractive power which consists of both convex positive lens and a **** negative lens, and both one convex positive lens and variable power is carried out to a tele edge from a wide angle edge the 1st lens group G1 -- a body side -- the locus of concave -- drawing -- moving -- a tele edge and a wide angle edge -- abbreviation -- becoming the same location, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and moves 3rd lens group G3 to an image surface side. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0097] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0098] The 1st lens group G1 of the negative refractive power which is from the positive meniscus lens of a convex on a both concave negative lens and body side as the zoom lens of an example 3 is shown in drawing 3, aperture-diaphragm S, To a body side at a positive meniscus lens [of a convex], and body side The cemented lens of the negative meniscus lens of a convex, It consists of 3rd lens group G3 of the forward refractive power which consists of both convex positive lens, and the 2nd lens group G2 of the forward refractive power which is from the negative meniscus lens of a convex on a body side and both one convex positive lens. the time of carrying out variable power to a tele edge from a wide angle edge -- the 1st lens group G1 -- a body side -- the locus of concave -- drawing -- moving -- a tele edge and a wide angle edge -- abbreviation -- becoming the same location, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 is immobilization. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0099] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0100] As the zoom lens of an example 4 is shown in drawing 4, to a body side Two negative meniscus lenses of a convex, At a positive meniscus lens [of a convex], and body side to a 1st lens group [of the negative refractive power which consists of both convex positive lens] G1, aperture-diaphragm S, and body side The cemented lens of the negative meniscus lens of a convex, It consists of 3rd lens group G3 of the forward refractive power which consists of both convex positive lens, and the 2nd lens group G2 of the forward refractive power which is from the negative meniscus lens of a convex on a body side and both one convex positive lens. In case variable power is carried out to a tele edge from a wide angle edge, the 1st lens group G1 draws the locus of concave, and moves to a body side. Becoming a location by the side of the image surface from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 draws the locus of a convex, and moves to a body side, and it becomes a location by the side of a body from a wide angle edge by the tele edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0101] The aspheric surface is used for the 3rd page, the field by the side of the image surface of the negative meniscus lens by the side of the body of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0102] As the zoom lens of an example 5 is shown in drawing 5, to a body side The negative meniscus lens of a convex, The 1st lens group G1 of negative refractive power, aperture-diaphragm S, the **** positive lens, and the cemented lens of a **** negative lens which are from the positive meniscus lens of a convex on a body side, In case it consists of 3rd lens group G3 of the forward refractive power which consists of the 2nd lens group G2 of the forward refractive power which consists of both convex positive lens and both concave negative lens, and both one convex positive lens and variable power is carried out to a tele edge from a wide angle edge The locus of concave is drawn and it moves to a body side, and by the tele edge, the 1st lens group G1 becomes a location by the side of the image surface from a wide angle edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 moves it for it to a body side. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0103] The aspheric surface is used for the 3rd page, the field by the side of the image surface of the negative meniscus lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0104] The 1st lens group G1 of negative refractive power, aperture-diaphragm S, both the convex positive lens, and the cemented lens of both the concave negative lens which are from the positive meniscus lens of a convex on a both concave negative lens and body side as the zoom lens of an example 6 is shown in drawing 6. In case it consists of 3rd lens group G3 of the forward refractive power which consists of the 2nd lens group G2 of the forward refractive power which consists of

both convex positive lens and both concave negative lens, and both one convex positive lens and variable power is carried out to a tele edge from a wide angle edge. The 1st lens group G1 draws the locus of concave on a body side, and it moves, and becomes a location by the side of the image surface from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, 3rd lens group G3 draws the locus of a convex on a body side, and it moves, and becomes a location by the side of the image surface from a wide angle edge in a tele edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0105] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0106] The 1st lens group G1 of negative refractive power, aperture-diaphragm S, both the convex positive lens, and the cemented lens of both the concave negative lens which are from the positive meniscus lens of a convex on a both concave negative lens and body side as the zoom lens of an example 7 is shown in [drawing 7](#). In case it consists of 3rd lens group G3 of the forward refractive power which consists of the 2nd lens group G2 of the forward refractive power which consists of both convex positive lens and both concave negative lens, and both one convex positive lens and variable power is carried out to a tele edge from a wide angle edge. The 1st lens group G1 draws the locus of concave on a body side, and it moves, and becomes a location by the side of a body from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, 3rd lens group G3 draws the locus of a convex on a body side, and it moves, and becomes the location same at a tele edge and wide angle edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0107] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0108] The 1st lens group G1 of the negative refractive power which is from the positive meniscus lens of a convex on a both concave negative lens and body side as the zoom lens of an example 8 is shown in [drawing 8](#), aperture-diaphragm S, To a body side at a positive meniscus lens [of a convex], and body side The cemented lens of the negative meniscus lens of a convex, It consists of 3rd lens group G3 of the forward refractive power which consists of both convex positive lens, and the 2nd lens group G2 of the forward refractive power which is from the negative meniscus lens of a convex on an image surface side and both one convex positive lens. In case variable power is carried out to a tele edge from a wide angle edge, the 1st lens group G1 draws the locus of concave, and moves to a body side. Becoming a location by the side of a body from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 draws the locus of a convex, and moves to an image surface side, and it becomes a location by the side of the image surface from a wide angle edge by the tele edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0109] The aspheric surface is used for the 3rd page, the field by the side of the image surface of both the concave negative lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the field by the side of the body of both the convex positive lens.

[0110] As the zoom lens of an example 9 is shown in [drawing 9](#), to a body side The negative meniscus lens of a convex, The 1st lens group G1 of negative refractive power, aperture-diaphragm S, the **** positive lens, and the cemented lens of a **** negative lens which are from the positive meniscus lens of a convex on a body side, It consists of 3rd lens group G3 of the forward refractive power which consists of both convex positive lens, and the 2nd lens group G2 of the forward refractive power which is from the negative meniscus lens of a convex on a body side and both one convex positive lens. In case variable power is carried out to a tele edge from a wide angle edge, the 1st lens group G1 draws the locus of concave on a body side, and it moves, and becomes a location by the side of the image surface from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 moves to a body side. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0111] The aspheric surface is used for the 3rd page of the fields by the side of the field by the side of the image surface of the negative meniscus lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the image surface of both the convex positive lens.

[0112] As the zoom lens of an example 10 is shown in [drawing 10](#), to a body side The negative meniscus lens of a convex, At a positive meniscus lens [of a convex], and body side to a 1st lens group [of the negative refractive power which is from the positive meniscus lens of a convex on a body side] G1, aperture-diaphragm S, and body side The cemented lens of the negative meniscus lens of a convex, It is from 3rd lens group G3 of the forward refractive power which consists of a positive meniscus lens of a convex, and the 2nd lens group G2 of the forward refractive power which becomes from the negative meniscus lens of a convex at an image surface side and both one convex positive lens on an image surface side. In case variable power is carried out to a tele edge from a wide angle edge, the 1st lens group G1 draws the locus of concave, and moves to a body side. Becoming a location by the side of the image surface from a wide angle edge in a tele edge, the 2nd lens group G2 moves to aperture-diaphragm S and one at a body side, and 3rd lens group G3 draws the locus of a convex, and moves to a body side, and it becomes a location by the side of a body from a wide angle edge by the tele edge. In order to carry out focusing to the photographic subject of a short distance, it lets out 3rd lens group G3 to a body side.

[0113] The aspheric surface is used for the 3rd page of the fields by the side of the field by the side of the image surface of the negative meniscus lens of the 1st lens group G1, the field by the side of the body of the cemented lens of the 2nd lens group G2, and the image surface of an independent positive meniscus lens.

[0114] Although the numeric data of each above-mentioned example is shown below In a notation, f outside the above a half-field angle and FNO for a whole system focal distance and omega The f number, For a wide angle edge and ST, an intermediate state and TE are [WE] a tele edge, r1, and r2. -- is the radius of curvature of each lens side, d1, and d2. -- is [the refractive index of d line of each lens, nud1, and nud2 -- of spacing between each lens side, nd1, and nd2 --] the Abbe numbers of each lens. In addition, an aspheric surface configuration uses x as the optical axis which made the travelling direction of light forward, and when y is taken in the direction which intersects perpendicularly with an optical axis, it is expressed with the following formula.

[0115] For $1 + \{1 - (K+1) (y/r)^2\}^{1/2} / x = (y^2 / r) / [2] + A_4 y^4 + A_6 y^6 + A_8 y^8 + A_{10} y^{10}$, however r, paraxial radius of curvature and K are a constant of the cone, A4, and A6, A8 and A10. It is the 4th aspheric surface multiplier [6th / 8th / 10th], respectively.

[0116]

Example 1r1 = -102.7129 d1 = 0.7000 nd 1 = 1.80610 nud1 =40.92 r2 = 5.3602 (aspheric surface) d2 = 2.0000 r3 = 11.4378 d3 = 1.8000 nd 2 = 1.84666 nud2 =23.78 r4 = 98.3090 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.9724 (aspheric surface) d6 = 2.0000 nd 3 = 1.80610 nud3 =40.92 r7 = -64.0363 d7 = 0.7000 nd 4 = 1.84666 nud4 =23.78 r8 = 7.0009 d8 =

1.1549 r9 = 15.2680 (aspheric surface) d9 = 1.3000 nd 5 = 1.69350 nud5 = 53.21 r10 = -12.7034 d10 = 0.1500 r11 = 91.7989 d11 = 0.7000 nd 6 = 1.80100 nud6 = 34.97 r12 = 8.2347 d12 = (adjustable) r13 = 11.7154 d13 = 1.8000 nd 7 = 1.48749 nud7 = 70.23 r14 = -20.5935 d14 = (adjustable) r15 = infinity d15 = 0.8000 nd 8 = 1.51633 nud8 = 64.14 r16 = infinity d16 = 1.5000 nd 9 = 1.54771 nud9 = 62.84 r17 = infinity d17 = 0.8000 r18 = infinity d18 = 0.7500 nd 10 = 1.51633 nud10 = 64.14 r19 = infinity d19 = 1.2097 r20 = infinity (image surface) The 2nd page of aspheric surface multiplier K = 0 A4 = -9.1908 x10-4 A6 = 1.0097 x10-5 A8 = -1.5014 x10-6 A10 = 0.0000 6th page K = 0 A4 = -1.4735 x10-4 A6 = 1.6281 x10-5 A8 = -7.9774 x10-7 A10 = 0.0000 The 9th page K = 0 A4 = -2.0216 x10-3 A6 = -1.8880 x10-4 A8 = 9.7090 x10-6 A10 = 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.50523 6.88872 12.89933 FNO 2.6065 3.5812 4.3925 omega (degree) 33.2 18.1 12.4d4 15.98285 5.88144 1.50000 d12 2.53628 8.66957 13.53479 d14 0.921730.42989 0.99810.

[0117]

Example 2r1 = -40.0207 d1 = 0.7000 nd 1 = 1.80610 nud1 = 40.92 r2 = 4.8393 (aspheric surface) d2 = 2.7104 r3 = 14.6390 d3 = 1.5606 nd 2 = 1.84666 nud2 = 23.78 r4 = -100.9877 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.5526 (aspheric surface) d6 = 1.8758 nd 3 = 1.80610 nud3 = 40.92 r7 = 15.8025 d7 = 0.9429 nd 4 = 1.84666 nud4 = 23.78 r8 = 4.0750 d8 = 0.6028 r9 = 7.1659 (aspheric surface) d9 = 1.8221 nd 5 = 1.69350 nud5 = 53.21 r10 = -8.0623 d10 = 0.1000 r11 = infinity d11 = 1.0000 nd 6 = 1.80100 nud6 = 34.97 r12 = 6.7380 d12 = (adjustable) r13 = 13.4670 d13 = 1.6540 nd 7 = 1.48749 nud7 = 70.23 r14 = -21.9112 d14 = (adjustable) r15 = infinity d15 = 0.8000 nd 8 = 1.51633 nud8 = 64.14 r16 = infinity d16 = 1.5000 nd 9 = 1.54771 nud9 = 62.84 r17 = infinity d17 = 0.8000 r18 = infinity d18 = 0.7500 nd 10 = 1.51633 nud10 = 64.14 r19 = infinity d19 = 1.2000 r20 = infinity (image surface) Aspheric surface multiplier The 2nd page K = 0 A4 = -1.6364 x10-3 A6 = 1.1356 x10-5 A8 = -2.5627 x10-6 A10 = 0.0000 6th page K = 0 A4 = -3.9899 x10-4 A6 = -2.2843 x10-5 A8 = -1.2585 x10-6 A10 = -9.0236 x10-9 The 9th page K = 0 A4 = -1.7288 x10-3 A6 = 4.6545 x10-5 A8 = -3.7671 x10-6 A10 = 3.6071 x10-7 zoom data (infinity)
WE ST Tef (mm) 4.20000 8.59999 12.80032 FNO 2.4980 3.5636 4.6676 omega (degree) 35.2 18.3 12.4d4 14.39292 4.31686 1.50000 d12 1.90425 8.66884 15.45557 d14 1.560491.52138 0.90000.

[0118]

Example 3r1 = -41.7871 d1 = 0.7000 nd 1 = 1.80610 nud1 = 40.92 r2 = 4.8061 (aspheric surface) d2 = 2.1538 r3 = 11.7830 d3 = 1.5885 nd 2 = 1.84666 nud2 = 23.78 r4 = 498.8711 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.4711 (aspheric surface) d6 = 1.8148 nd 3 = 1.80610 nud3 = 40.92 r7 = 16.1235 d7 = 0.8513 nd 4 = 1.84666 nud4 = 23.78 r8 = 4.0848 d8 = 0.5201 r9 = 6.1325 (aspheric surface) d9 = 1.6063 nd 5 = 1.69350 nud5 = 53.21 r10 = -11.1687 d10 = 0.1000 r11 = 16.3851 d11 = 1.0000 nd 6 = 1.80100 nud6 = 34.97 r12 = 4.8782 d12 = (adjustable) r13 = 17.5725 d13 = 1.7579 nd 7 = 1.48749 nud7 = 70.23 r14 = -13.0293 d14 = 0.9000 r15 = infinity d15 = 0.8000 nd 8 = 1.51633 nud8 = 64.14 r16 = infinity d16 = 1.5000 nd 9 = 1.54771 nud9 = 62.84 r17 = infinity d17 = 0.8000 r18 = infinity d18 = 0.7500 nd 10 = 1.51633 nud10 = 64.14 r19 = infinity d19 = 1.2001 r20 = infinity (image surface) Aspheric surface multiplier The 2nd page K = 0 A4 = -1.5240 x10-3 A6 = 7.1028 x10-6 A8 = -2.5635 x10-6 A10 = 0.0000 6th page K = 0 A4 = -4.1354 x10-4 A6 = -2.4486 x10-5 A8 = -1.4312 x10-6 A10 = 3.7941 x10-8 The 9th page K = 0 A4 = -1.7166 x10-3 A6 = 5.3328 x10-5 A8 = -4.9514 x10-6 A10 = -5.3554 x10-8 zoom data (infinity)
WE ST Tef (mm) 4.20005 8.60008 12.80003 FNO </SUB> 2.6418 3.7743 4.8647 omega (degree) 35.2 18.3 12.5d4 13.62386 4.39163 1.50000 d12 2.13358 8.33646 14.25744 .

[0119]

Example 4r1 = 27.0909 d1 = 0.7000 nd 1 = 1.80610 nud1 = 40.92 r2 = 6.6293 (aspheric surface) d2 = 1.8000 r3 = 144.3405 d3 = 0.7000 nd 2 = 1.80100 nud2 = 34.97 r4 = 8.3285 d4 = 0.8000 r5 = 9.3403 d5 = 1.8000 nd 3 = 1.80518 nud3 = 25.42 r6 = -172.3059 d6 = (adjustable) r7 = infinity (diaphragm) d7 = 1.2000 r8 = 4.6685 (aspheric surface) d8 = 2.0000 nd 4 = 1.80610 nud4 = 40.92 r9 = 39.3390 d9 = 0.7000 nd 5 = 1.84666 nud5 = 23.78 r10 = 6.3668 d10 = 1.0180 r11 = 21.8104 (aspheric surface) d11 = 1.3000 nd 6 = 1.69350 nud6 = 53.21 r12 = -13.5364 d12 = 0.1500 r13 = 38.5671 d13 = 0.7000 nd 7 = 1.80518 nud7 = 25.42 r14 = 8.0481 d14 = (adjustable) r15 = 9.5072 d15 = 1.8000 nd 8 = 1.48749 nud8 = 70.23 r16 = -24.4883 d16 = (adjustable) r17 = infinity d17 = 0.8000 nd 9 = 1.51633 nud9 = 64.14 r18 = infinity d18 = 1.5000 nd 10 = 1.54771 nud10 = 62.84 r19 = infinity d19 = 0.8000 r20 = infinity d20 = 0.7500 nd 11 = 1.51633 nud11 = 64.14 r21 = infinity d21 = 1.2108 r22 = infinity (image surface) aspheric surface multiplier The 2nd page K = 0 A4 = -2.9630 x10-4 A6 = 4.2847 x10-6 A8 = -3.6003 x10-7 A10 = 0.0000 8th page K = 0 A4 = -2.6881 x10-4 A6 = 2.5560 x10-5 A8 = -3.5822 x10-7 A10 = 0.0000 The 11th page K = 0 A4 = -2.1333 x10-3 A6 = -2.4378 x10-4 A8 = 3.2564 x10-7 A10 = 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.48846 8.69183 12.90297 FNO 2.5989 3.4016 4.5450 omega (degree) 33.4 18.4 12.5d6 14.80359 3.81650 1.50000 d14 2.53628 7.33575 14.91963 d16 0.921731.86494 0.99412.

[0120]

Example 5r1 = 208.2759 d1 = 0.7000 nd 1 = 1.74320 nud1 = 49.34 r2 = 4.6930 (aspheric surface) d2 = 2.0000 r3 = 8.5950 d3 = 1.8000 nd 2 = 1.80518 nud2 = 25.42 r4 = 20.6048 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.2440 (aspheric surface) d6 = 2.0000 nd 3 = 1.80610 nud3 = 40.92 r7 = infinity d7 = 0.7000 nd 4 = 1.84666 nud4 = 23.78 r8 = 5.0693 d8 = 0.6000 r9 = 24.7066 (aspheric surface) d9 = 1.3000 nd 5 = 1.69350 nud5 = 53.21 r10 = -10.1759 d10 = 0.1500 r11 = -266.8373 d11 = 0.7000 nd 6 = 1.80100 nud6 = 34.97 r12 = 14.0737 d12 = (adjustable) r13 = 20.4220 d13 = 1.8000 nd 7 = 1.48749 nud7 = 70.23 r14 = -14.3628 d14 = (adjustable) r15 = infinity d15 = 0.8000 nd 8 = 1.51633 nud8 = 64.14 r16 = infinity d16 = 1.5000 nd 9 = 1.54771 nud9 = 62.84 r17 = infinity d17 = 0.8000 r18 = infinity d18 = 0.7500 nd 10 = 1.51633 nud10 = 64.14 r19 = infinity d19 = 1.2092 r20 = infinity (image surface) The 2nd page of aspheric surface multiplier K = 0 A4 = -1.1214 x10-3 A6 = 3.1893 x10-5 A8 = -4.1833 x10-6 A10 = 0.0000 6th page K = 0 A4 = -1.7255 x10-5 A6 = -4.4178 x10-5 A8 = 9.1087 x10-6 A10 = 0.0000 The 9th page K = 0 A4 = -3.5926 x10-3 A6 = -7.1592 x10-5 A8 = -6.8024 x10-5 A10 = 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.52199 8.69159 12.89618 FNO 2.6728 3.5913 4.5324 omega (degree) 33.2 18.1 12.4d4 13.53589 4.62823 1.50000 d12 2.53628 7.65616 12.90171 d14 0.921730.98067 1.00178.

[0121]

Example 6r1 = -115.4675 d1 = 0.7000 nd 1 = 1.80610 nud1 = 40.92 r2 = 5.0884 (aspheric surface) d2 = 2.4077 r3 = 11.8048 d3 = 1.5055 nd 2 = 1.84666 nud2 = 23.78 r4 = 79.1966 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.9875 (aspheric surface) d6 = 2.2097 nd 3 = 1.80610 nud3 = 40.92 r7 = -92.9504 d7 = 0.7000 nd 4 = 1.84666 nud4 = 23.78 r8 = 7.0480 d8 = 1.7157 r9 = 20.4501 (aspheric surface) d9 = 1.4488 nd 5 = 1.69350 nud5 = 53.21 r10 = -5.4179 d10 = 0.2153 r11 = -6.0014 d11 = 1.0000 nd 6 = 1.80100 nud6 = 34.97 r12 = 56.3492 d12 = (adjustable) r13 = 12.4691 d13 = 1.6359 nd 7 = 1.48749 nud7 = 70.23 r14 = -24.0279 d14 = (adjustable) r15 = infinity d15 = 0.8000 nd 8 = 1.51633 nud8 = 64.14 r16 = infinity d16 = 1.5000 nd 9 = 1.54771 nud9 = 62.84 r17 = infinity d17 = 0.8000 r18 = infinity d18 = 0.7500 nd 10 = 1.51633 nud10 = 64.14 r19 = infinity d19 = 1.1985 r20 = infinity (image surface) The 2nd page of aspheric surface multiplier K = 0 A4 = -1.0638 x10-3 A6 = 2.1512 x10-6 A8 = -1.6979 x10-6 A10 = 0.0000 6th page K = 0 A4 = -2.6779 x10-4 A6 = 1.4102 x10-6 A8 = -8.0728 x10-7 A10 = 0.0000 The 9th page K = 0 A4 = -2.1523 x10-3 A6 = -8.1365 x10-5 A8 = -5.0480 x10-6 A10 = 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.49939 8.59837 12.79887 FNO 2.6057 3.4199 4.4288 omega (degree) 33.2 18.4 12.5d4 14.90728 4.50456 1.50000 d12 2.34564 7.26336 13.74810 d14 0.958501.50353 0.90000.

[0122]

Example 7r1 = -552.0327 d1 = 0.7000 nd 1 = 1.80610 nud1 =40.92 r2 = 4.3477 (aspheric surface) d2 = 1.6776 r3 = 8.2917 d3 = 1.5233 nd 2 = 1.84666 nud2 =23.78 r4 = 25.4637 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.7104(aspheric surface) d6 = 1.9721nd3 = 1.80610 nud3 =40.92 r7 = -33.7287 d7 = 0.7000 nd 4 = 1.84666 nud4 =23.78r8 = 7.9668d8 = 1.9478r9 = 22.3098 (aspheric surface) d9 = 1.3699 nd 5 = 1.69350 nud5 =53.21 r10=-5.5074 d10= 0.1000 r11=-6.0325 d11= 1.0000 nd 6 = 1.80100 nud6 =34.97 r12= 52.7538 d12= r(adjustable)13= 15.2026 d13= 1.7414 nd 7 = 1.48749 nud7 =70.23 r14= -14.4840 d14= (adjustable) r15= infinity d15= 0.8000 nd 8 = 1.51633 nud8 =64.14 r16= infinity d16= 1.5000 nd 9 = 1.54771 nud9 =62.84 r17= infinity d17= 0.8000 r18= infinity d18= 0.7500 nd 10= 1.51633 nud10=64.14 r19= infinity d19= 1.2000 r20= infinity (image surface) Aspheric surface multiplier The 2nd page K = 0 A4 =-1.4967x10⁻³ A6 = 1.2766 x10⁻⁵ A8 =-5.5780 x10⁻⁶ A10= 0.0000 The 6th page K = 0 A4 =-3.4707 x10⁻⁴ A6 = 2.7502 x10⁻⁶ A8 =-8.5549 x10⁻⁷ A10= 0.0000 The 9th page K = 0 A4 =-2.6615 x10⁻³ A6 =-9.6885 x10⁻⁵ A8 =-1.1909 x10⁻⁵ A10= 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.50002 8.89986 12.79811 FNO 2.6022 3.5568 4.6259omega (degree) 33.1 17.8 12.6d4 10.91791 3.18224 1.50000d12 1.70000 7.41371 14.11791 d14 0.900001.65812 0.90000.

[0123]

Example 8r1 = -34.8037 d1 = 0.7000 nd 1 = 1.80610 nud1 =40.92 r2 = 4.1900 (aspheric surface) d2 = 1.1999 r3 = 8.0659 d3 = 1.6447 nd 2 = 1.84666 nud2 =23.78 r4 = 48.7210 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 3.8631(aspheric surface) d6 = 1.7680nd3 = 1.80610 nud3 =40.92 r7 = 62.8242 d7 = 0.7000 nd 4 = 1.84666 nud4 =23.78r8 = 4.5969d8 = 2.3429r9 = 13.0143 (aspheric surface) d9 = 1.4756 nd 5 = 1.69350 nud5 =53.21 r10=-7.3240 d10= 0.1000 r11=-6.0586 d11= 1.0000 nd 6 = 1.80100 nud6 =34.97 r12= -25.9560 d12= r(adjustable)13= 44.0311 d13= 1.6462 nd 7 = 1.48749 nud7 =70.23 r14= -10.9953 d14= (adjustable) r15= infinity d15= 0.8000 nd 8 = 1.51633 nud8 =64.14 r16= infinity d16= 1.5000 nd 9 = 1.54771 nud9 =62.84 r17= infinity d17= 0.8000 r18= infinity d18= 0.7500 nd 10= 1.51633 nud10=64.14 r19= infinity d19= 1.1968 r20= infinity (image surface) Aspheric surface multiplier The 2nd page K = 0 A4 =-2.0325x10⁻³ A6 =-5.3892 x10⁻⁶ A8 =-6.1267 x10⁻⁶ A10= 0.0000 The 6th page K = 0 A4 =-7.6210 x10⁻⁴ A6 =-2.6462 x10⁻⁵ A8 =-4.0575 x10⁻⁶ A10=-1.4214 x10⁻⁸ The 9th page K= 0 A4 =-1.9457 x10⁻³ A6 =-9.6412 x10⁻⁵ A8 = 9.3922 x10⁻⁷ A10=-3.1543 x10⁻⁶ zoom data (infinity)
WE ST Tef (mm) 4.49848 8.59759 12.79866 FNO 2.6659 3.7467 4.6171omega (degree) 33.2 18.5 12.7d4 10.65871 4.48879 1.50000d12 1.89640 8.96466 14.27271 d14 1.117600.02771 0.90000.

[0124]

Example 9r1 = 354.9584 d1 = 0.7000 nd 1 = 1.80610 nud1 =40.92 r2 = 4.6698 (aspheric surface) d2 = 2.0000 r3 = 9.2747 d3 = 1.8000 nd 2 = 1.84666 nud2 =23.78 r4 = 29.2897 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.7808(aspheric surface) d6 = 2.0000nd3 = 1.80610 nud3 =40.92 r7 = -100.0000 d7 = 0.7000 nd 4 = 1.84666 nud4 =23.78r8 = 7.1229d8 = 0.9250r9 = 11.1248 d9 = 1.3000 nd5 =1.69350nud5 =53.21 r10= -575.7637 (aspheric surface) d10= 0.1500 r11= 149.0119 d11= 0.7000 nd 6 = 1.84666 nud6 =23.78 r12= 16.0252 d12= (adjustable) r13= 18.2359 d13= 1.8000 nd 7 = 1.48749 nud7 =70.23 r14=-16.5835 d14= (adjustable) r15= infinity d15= 0.8000 nd 8 = 1.51633 nud8 =64.14 r16= infinity d16= 1.5000 nd 9 = 1.54771 nud9 =62.84 r17= infinity d17= 0.8000 r18= infinity d18= 0.7500nd 10= 1.51633 nud10=64.14 r19= infinity d19= 1.2099 r20= infinity (image surface) aspheric surface multiplier The 2nd page K= 0 A4 =-1.1690 x10⁻³ A6 =-1.7413 x10⁻⁵ A8 =-3.7161 x10⁻⁶A10= 0.0000 6th page K = 0 A4 =-8.5856x10⁻⁵A6 = 1.6399 x10⁻⁶ A8 =-4.4906 x10⁻⁸ A10= 0.0000 The 10th page K = 0 A4 = 3.0886 x10⁻³ A6 = 7.0935 x10⁻⁵ A8 = 2.3661 x10⁻⁵ A10= 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.50424 8.68935 12.89934 FNO 2.6359 3.5740 4.5352omega (degree) 33.3 18.1 12.4d4 13.20936 4.52377 1.50000d12 2.53628 7.86108 13.31534 d14 0.921730.98683 0.99884.

[0125]

Example 10r1 = 84.8334 d1 = 0.7000 nd 1 = 1.74320 nud1 =49.34 r2 = 4.8594 (aspheric surface) d2 = 2.0000 r3 = 9.0964 d3 = 1.8000 nd 2 = 1.84666 nud2 =23.78 r4 = 18.5606 d4 = (adjustable) r5 = infinity (diaphragm) d5 = 1.2000 r6 = 4.2563(aspheric surface) d6 = 2.0000nd3 = 1.80610 nud3 =40.92 r7 = 100.0000 d7 = 0.7000 nd 4 = 1.84666 nud4 =23.78r8 = 6.3678d8 = 0.4000r9 = -34.3924 d9 = 1.3000 nd5 =1.69350nud5 =53.21 r10= -8.0179 (aspheric surface) d10= 0.3000 r11= -8.3805 d11= 0.7000 nd 6 = 1.84666 nud6 =23.78 r12= -21.0856 d12= (adjustable) r13= 14.6488 d13= 1.8000 nd 7 = 1.48749 nud7 =70.23 r14=-20.2077 d14= (adjustable) r15= infinity d15= 0.8000 nd 8 = 1.51633 nud8 =64.14 r16= infinity d16= 1.5000 nd 9 = 1.54771 nud9 =62.84 r17= infinity d17= 0.8000 r18= infinity d18= 0.7500nd 10= 1.51633 nud10=64.14 r19= infinity d19= 1.2068 r20= infinity (image surface) aspheric surface multiplier The 2nd page K= 0 A4 =-1.0284 x10⁻³ A6 = 3.3497 x10⁻⁵ A8 =-3.4598 x10⁻⁶A10= 0.0000 6th page K = 0 A4 =-5.8749x10⁻⁵A6 =-9.9305 x10⁻⁶ A8 =6.6151 x10⁻⁶ A10= 0.0000 The 10th page K = 0 A4 = 3.5852 x10⁻³ A6 = 2.6012 x10⁻⁴ A8 = 4.5257 x10⁻⁵ A10= 0.0000 Zoom data (infinity)
WE ST Tef (mm) 4.51247 8.69085 12.90169 FNO 2.7040 3.5173 4.5477omega (degree) 33.2 18.1 12.3d4 13.56120 4.06037 1.50000d12 2.53628 6.76140 13.02411 d14 0.921731.69971 1.00981.

[0126] The aberration Fig. at the time of the infinite distance object point focus of the above example 1, and photographic subject distance the focus of 10cm is shown in [drawing 11](#) and [drawing 12](#), respectively. In these aberration Figs., (a) shows the spherical aberration [in / a wide angle edge and (b), and / in (c) / a tele edge] SA, Astigmatism AS, the distortion aberration DT, and the chromatic aberration of magnification CC. [an intermediate state] "FIY" expresses image quantity among drawing.

[0127] In addition, the criteria of the amount of deflections of the field and the becoming radius of curvature r of the criteria spherical surface are shown as ra of the field (a is a field number) about the aspheric surface indicated in the above-mentioned example.

[0128] Next, Asp21F about the value of condition (1) - (5) and (7) - in each above-mentioned example (17), and conditions (6) and Asp2R And the value of L is shown.

Example 1 2 3 4 5 (1) 1.40795 0.89509 0.91360 1.36378 1.19446 (2) 0.50176 0.69462 0.84327 0.55884 0.52936 (3) 0.02679 0.01786 0.01786 0.02679 0.02679 (4) 0.10067 0.45293 0.48599 0.05301 0.21846 (5) 35.38000 35.3800035.38000 44.93000 35.38000 (7) -0.16942 0.05535 0.04515 -0.15390 -0.08862 (8) 0.28050 1.40535 1.35749 0.135340.68642 (9) 0.20624 0.10763 0.09287 0.18179 0.10714 (10) -0.22380 2.21234 2.06386 0.34032 0.00000 (11) 0.20618 0.91029 0.89705 0.10983 0.39782 (12) -0.27479 -0.23868 0.14846-0.44068 0.17419 (13) 1.0 1.0 1.0 1.0 1.0 (14) 0.04 0.04 0.04 0.04 0.04 (15) 0.0 0.0 0.0 0.0 0.0 (16) 1.06 1.06 1.06 1.06 1.06 (17) 0.333 0.333 0.333 0.333 (a= 3.0) (a= 3.0) (a= 3.0) (a= 3.0) Asp21F -0.00086 - 0.00377 -0.00393 -0.00055 -0.00159 Asp2R -0.01973 -0.01290-0.01280 -0.03454 -0.02245L 5.6 5.6 5.6 5.6 5.6 .
Example 6 7 8 9 10 (1) 1.4130 1.6913 1.1900 1.48990 1.49609 (2) 0.10050 0.08851 -0.02852 0.04735 0.03011 (3) 0.03845 0.01786 0.01786 0.02679 0.05357 (4) 0.11252 0.06773 0.26914 0.11434 0.04250 (5) 35.38000 35.38000 35.38000 46.57000 46.57000 (7) -0.17120 -0.25687 -0.08674 -0.19676 -0.19874 (8) 0.34339 0.18764 0.87599 0.370050.13448 (9) 0.30638 0.34782 0.41838 0.16517 0.07143 (10) -0.14892 -0.32727 0.20611 -0.12627 0.10616 (11) 0.22705 0.11962 0.46776 0.20849 0.07773 (12) -0.31671 0.02420 0.60036 0.04746 -0.15948 (13) 1.0 1.0 1.0 1.0 1.0 (14) 0.04 0.04 0.04 0.04 0.04 (15) 0.0 0.0 0.0 0.0 0.0 (16) 1.06 1.06 1.06 1.06 1.06 (17) 0.333 0.333 0.333 0.3330.333 (a= 3.0) (a= 3.0) (a= 3.0) (a= 3.0) (a= 3.0) Asp21F -0.00215 - 0.00276-0.00693 -0.00065 -0.00027Asp2R -0.01929-0.02414-0.01817 0.02770 0.03728 L 5.6 5.6 5.6 5.6 5.6 .

[0129] In addition, total thickness tLPF of the low pass filter LF of examples 1-10 The three-sheet pile constitutes each

from 1.500 (mm). Of course, an above-mentioned example can be variously changed within the limits of configurations of having described above, such as constituting for example, the low pass filter LF from one sheet.

[0130] Here, the diagonal length L and the pixel spacing a of an effective image pick-up side are explained. Drawing 14 is drawing showing one example of the pixel array of an image sensor, and the pixel (drawing 14) of the pixel of R (red), G (green), and B (blue) or cyanogen, MAZENDA, yellow, and four colors of Green (green) is allotted in the shape of a mosaic at intervals of [a] the pixel. An effective image pick-up side means the field within the photo-electric-conversion side on the image sensor used for playbacks (the display on a personal computer, printing by the printer, etc.) of the photoed image. The effective image pick-up side shown all over drawing is set as the field narrower than all the photo-electric-conversion sides of an image sensor to compensate for the engine performance (image circle which the engine performance of optical system can secure) of optical system. The diagonal length L of an effective image pick-up side is diagonal length of this effective image pick-up side. In addition, although it is good as modification being possible in various image pick-up range used for playback of an image, in case the zoom lens of this invention is used for the image pick-up equipment which has such a function, the diagonal length L of the effective image pick-up side changes. In such a case, the diagonal length L of the effective image pick-up side in this invention is taken as the maximum in the range which L can take.

[0131] Moreover, about an infrared cut means, there are infrared cut absorption filter IF and an infrared Sharp cut coat, and an infrared Sharp cut coat is not absorption but the cut by reflection in the case where an infrared-absorption object contains infrared cut absorption filter IF in glass. therefore -- said -- as carried out, this infrared cut absorption filter IF may be removed, a direct infrared Sharp cut coat may be given to a low pass filter LF, and you may give on dummy transparence monotonous.

[0132] As for the near-infrared Sharp cut coat in this case, it is desirable for permeability with a wavelength of 600nm to constitute 80% or more, so that permeability with a wavelength of 700nm may become 10% or less. Specifically, they are the multilayers which consist of the following lamination of 27 layers. However, design wavelength is 780nm.

[0133]

Radical Plate The quality of the material Physical thickness (nm) lambda/4 ----- The 1st layer aluminum 203 58.96 0.50 The 2nd layer TiO2 84.19 1.00 The 3rd layer SiO2 134.14 1.00 The 4th layer TiO2 84.19 1.00 The 5th layer SiO2 134.14 1.00 The 6th layer TiO2 84.19 The 1.00 7th layer SiO2 134.141.00 The 8th layer TiO2 84.19 1.00 The 9th layer SiO2 134.14 The 1.00 10th layer TiO2 84.19 1.00 The 11th layer SiO2 134.141.00 The 12th layer TiO2 84.19 1.00 The 13th layer SiO2 134.14 1.00 The 14th layer TiO2 84.19 1.00 The 15th layer SiO2 178.41 1.33 The 16th layer TiO2 101.03 1.21 The 17th layer SiO2 167.67 1.25 The 18th layer TiO2 96.821.15 The 19th layer SiO2 147.55 1.05 The 20th layer TiO2 84.19 1.00 The 21st layer SiO2 160.97 1.20 The 22nd layer TiO2 84.19 1.00 The 23rd layer SiO2 154.26 1.15 The 24th layer TiO2 95.13 1.13 The 25th layer SiO2 160.97 1.20 The 26th layer TiO2 99.34 1.18 The 27th layer SiO2 87.19 0.65 ----- sky Mind .

[0134] The permeability property of the above-mentioned near-infrared Sharp cut coat is as being shown in drawing 15 .

[0135] Moreover, the color reproduction nature of an electronic image is further raised to the injection side side of a low pass filter LF by preparing the color filter which low-** transparency of the color of a short wavelength region as shown in drawing 16 , or performing coating.

[0136] The ratio [as opposed to the permeability of wavelength with the highest permeability by this filter or coating] of permeability with a wavelength of 420nm is 15% or more on the wavelength of 400nm - 700nm, and, specifically, it is desirable that the ratio of permeability with a wavelength of 400nm to the permeability of that highest wavelength is 6% or less.

[0137] Thereby, the gap with the recognition over the color of human being's eyes and the color of the image picturized and reproduced can be reduced. In other words, with human being's vision, degradation of the image by the color by the side of the short wavelength which is hard to be recognized being easily recognized by human being's eyes can be prevented.

[0138] If the ratio of permeability with an above-mentioned wavelength of 400nm exceeds 6%, the wavelength which the single wavelength castle which is hard to be recognized by human being's eyes can recognize will be reproduced, conversely, if the ratio of permeability with an above-mentioned wavelength of 420nm is smaller than 15%, playback of the wavelength castle which human being can recognize will become low, and the balance of a color will worsen.

[0139] A means to restrict such wavelength takes effect more in the image pick-up system which used the complementary color mosaic filter.

[0140] In each above-mentioned example, as shown in drawing 16 , permeability [in / for the permeability in the wavelength of 400nm / 420nm] is made into coating which becomes peak 100% of permeability in 440nm 90% 0%.

[0141] By crossing of an operation with the above mentioned near-infrared Sharp cut coat, permeability [in / for permeability / in / for permeability / in / for the permeability in 400nm / 420nm / 600nm / 700nm] is made into 2% 82% 80% 0% with a peak of 99% of permeability with a wavelength of 450nm. Thereby more faithful color reproduction is performed.

[0142] Moreover, whenever [azimuth / at the time of projection on the image surface] is using in piles three kinds of filters which have a crystallographic axis in a horizontal (= 0 degree) and the direction of **45 degree, respectively in the direction of an optical axis, and about each, a low pass filter LF is shifting only SQRT (1/2) x a in amum and the direction of **45 degree horizontally, respectively, and is performing moire control. Here, SQRT is the square root as mentioned above, and means a square root.

[0143] Moreover, on the image pick-up side I of CCD, cyanogen, MAZENDA, yellow, and the complementary color mosaic filter that prepared the color filter of four colors of Green (green) in the shape of a mosaic corresponding to the image pick-up pixel are prepared as shown in drawing 17 . these four kinds of color filters -- each -- abbreviation -- it is arranged in the shape of a mosaic so that it may become the same number, and so that it may not correspond to the color filter of the class with the same adjacent pixel. Thereby more faithful color reproduction becomes possible.

[0144] A complementary color mosaic filter consists of at least four kinds of color filters, as shown in drawing 17 , and specifically, it is [the property of four kinds of the color filter] desirable that it is as follows.

[0145] color filter G of Green -- wavelength GP a spectrum -- a strong peak -- having -- color filter Ye of yellow Wavelength YP a spectrum -- a strong peak -- having -- color filter C of cyanogen -- wavelength CP a spectrum -- having a strong peak, color filter M of MAZENDA has a peak on wavelength MP1 and MP2, and is satisfied with it of the following conditions.

[0146] $2 < 640\text{nm}$ of $1 < 480\text{nm}$ $580\text{nm} < \text{MP}$ of $510\text{nm} < \text{GP}$ $< 540\text{nm}$ $5\text{nm} < \text{YP}$ $\text{GP} < 35\text{nm}$ $100\text{nm} < \text{CP}$ $\text{GP} < 5\text{nm}$ $430\text{nm} < \text{MP}$ further On the wavelength of 530nm, it has 80% or more of reinforcement to a strong peak. the color filter of Green, yellow, and cyanogen -- each spectrum -- As for the color filter of MAZENDA, it is more desirable to have 10 to 50% of reinforcement on the wavelength of 530nm to the peak of optical reinforcement that much, when raising color reproduction nature.

[0147] An example of each wavelength property in each above-mentioned example is shown in drawing 18 . color filter G of Green -- 525nm -- a spectrum -- it has the strong beak. color filter Ye of yellow 555nm -- a spectrum -- it has the strong

peak. color filter C of cyanogen -- 510nm -- a spectrum -- it has the strong peak. Color filter M of MAZENDA has the peak in 445nm and 620nm. moreover, each color filter in 530nm -- each spectrum -- a strong peak -- receiving -- G -- 99% and Ye C is and M may be 38% 97% 95%.

[0148] In the case of such a complementary filter, the controller (or controller used for a digital camera) which is not illustrated performs the following signal processing electrically, and it is a luminance signal.

$Y = |G + M + Ye + C| \times 1/4$ chrominance signal

It is changed into the signal of R (red), G (green), and B (blue) through signal processing of $R - Y = [(M + Ye) - (G + C)]$, $B - Y = [(M + C) - (G + Ye)]$.

[0149] By the way, the arrangement location of the above-mentioned near-infrared Sharp cut coat may be any location on an optical path. Moreover, two sheets or at least one sheet does not matter as the number of sheets of a low pass filter LF was also described above.

[0150] Now, the above electronic image pick-up equipments of this invention can especially be used for the photography equipment which takes a photograph by forming a body image with a zoom lens and making electronic image sensors, such as CCD, receive the image, a digital camera, a video camera and the personal computer that is the example of an information processor, a telephone, especially a cellular phone convenient to carry, etc. Below, the operation gestalt is illustrated.

[0151] Drawing 19 - drawing 21 show the conceptual diagram of a configuration of having built the zoom lens by this invention into the photography optical system 41 of a digital camera. It is the sectional view in which the front perspective view in which drawing 19 shows the appearance of a digital camera 40, and drawing 20 show this back perspective view, and drawing 21 shows the configuration of a digital camera 40. If a digital camera 40 presses the shutter 45 arranged in the upper part of a camera 40 including the photography optical system 41 which has the optical path 42 for photography, the finder optical system 43 which has the optical path 44 for finders, a shutter 45, a flash plate 46, and liquid crystal display monitor 47 grade in the case of this example, it will be interlocked with and photography will be performed through the zoom lens of the photography optical system 41. For example, an example. The body image formed of the photography optical system 41 is formed on the image pick-up side of CCD49 through infrared cut absorption filter IF which comes to give a near-infrared cut coat on dummy transparency monotonous, and the optical low pass filter LF. The body image received by this CCD49 is displayed on the liquid crystal display monitor 47 formed in the camera tooth back as an electronic image through the processing means 51. Moreover, it connects with this processing means 51, and the record means 52 can also record the photoed electronic image on it. In addition, this record means 52 may be formed in the processing means 51 and another object, and it may be constituted so that a floppy (trademark) disk, memory card, MO, etc. may perform a record store electronically. Moreover, you may constitute as a film-based camera which has arranged the silver halide film instead of CCD49.

[0152] Furthermore, on the optical path 44 for finders, the object optical system 53 for finders is arranged. The body image formed of this object optical system 53 for finders is formed on the visual field frame 57 of the Porro prism 55 which is an image erection member. Behind this polyp rhythm 55, the eyepiece optical system 59 which leads the image made into the erect normal image to the observer eyeball E is arranged. In addition, the covering member 50 is arranged at the injection side of the eyepiece optical system 59, respectively the incidence side of the photography optical system 41 and the object optical system 53 for finders.

[0153] Thus, the photography optical system 41 is a high variable power ratio in an extensive field angle, aberration is good and the constituted digital camera 40 has it, and since it is the big zoom lens of the back focus which can arrange a filter etc., it can realize high performance and low cost-ization. [bright]

[0154] In addition, in the example of drawing 21, although the plane-parallel plate is arranged as a covering member 50, a lens with power may be used.

[0155] The electronic image pick-up equipment which has the zoom lens of the above this invention and it can be constituted as follows, for example.

[0156] [1] The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power. Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is the zoom lens characterized by for which lens having the aspheric surface and satisfying the following conditions (1) of the positive lens L23 in said 2nd lens group, or a negative lens L24 at least.

[0157]

(1) $0.6 < R22R/R21F < 2.2$ however $R21F$, and $R22R$ It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of the negative lens L22 of the 2nd lens group, respectively.

[0158] [2] The above-mentioned 1 written zoom lens characterized by uniting with the electronic image sensor arranged on an image side.

[0159] In the zoom lens arranged on the image pick-up side side of an electronic image sensor [3] Said zoom lens The 1st lens group which has negative refractive power in order [side / body], and the 2nd lens group which has forward refractive power. Consist of the 3rd lens group which has forward refractive power, and the variable power from the wide angle edge at the time of an infinite distance object point focus to a tele edge is faced. Said 2nd lens group moves only to a body side, and it moves, said 3rd lens group changing spacing with the 2nd lens group. Said 2nd lens group Sequentially from a body side, it consists of a positive lens L21, a negative lens L22, a positive lens L23, and a negative lens L24. It is the zoom lens characterized by for which lens having the aspheric surface and satisfying the following conditions (2) of the positive lens L23 in said 2nd lens group, or a negative lens L24, (3), and (4) at least.

[0160]

(2) $0 < (C24F - C23R)$ and $L < 1.6$ (3) $0.01 < d23 / L < 0.2$ (4) It corrects $-0.4 < L/f2R < 0.8$. $C23R = 1/R23R$, and $C24F = 1/R24F$ it is -- here $R23R$ and $R24F$, respectively The field by the side of the image of the positive lens L23 of the 2nd lens group, The radius of curvature on the optical axis of the field by the side of the body of the negative lens L24 of the 2nd lens group and L The diagonal length of the effective image pick-up field (abbreviation rectangle) of an image sensor (mm), Optical-axis absentminded mind spacing of the positive lens L23 of the 2nd lens group and a negative lens L24 and $f2R$ of $d23$ are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0161] [4] The zoom lens of one above-mentioned publication characterized by uniting with the electronic image sensor arranged on an image side, and satisfying the following conditions (2), (3), and (4).

[0162]

(2) $0 < (C24F - C23R)$ and $L < 1.6$ (3) $0.01 < d23 / L < 0.2$ (4) It corrects $-0.4 < L/f2R < 0.8$. $C23R = 1/R23R$, and $C24F = 1/R24F$ it is

-- here R23R and R24F, respectively The field by the side of the image of the positive lens L23 of the 2nd lens group, The radius of curvature on the optical axis of the field by the side of the body of the negative lens L24 of the 2nd lens group and L The diagonal length of the effective image pick-up field (abbreviation rectangle) of an image sensor (mm), Optical-axis absentminded mind spacing of the positive lens L23 of the 2nd lens group and a negative lens L24 and f2R of d23 are the synthetic focal distances of the positive lens L23 of the 2nd lens group, and a negative lens L24.

[0163] [5] The zoom lens of four given in any 1 term from the above 2 characterized by joining the positive lens L21 and negative lens L22 of said 2nd lens group.

[0164] [6] The zoom lens of the above 2-5 characterized by said 2nd lens group satisfying the following conditions (5) given in any 1 term.

[0165]

(5) $25 < \nu_{21} - \nu_{22} + \nu_{23} - \nu_{24} < 55$, however ν_{21} , ν_{22} , ν_{23} and ν_{24} are the Abbe numbers (d line standard) of the medium of the positive lens L21 of the 2nd lens group, a negative lens L22, a positive lens L23, and a negative lens L24, respectively.

[0166] [7] The zoom lens of the above 2-6 characterized by any satisfying at least the following conditions (6) of said aspheric surface of the positive lens L23 in said 2nd lens group, or a negative lens L24 allotted for any being at least given in any 1 term.

[0167]

(6) 7.5×10^{-3} and $L > |Asp_{2R}| > |Asp_{21F}|$ It corrects. Asp_{21F} and Asp_{2R} , respectively The field by the side of the body of a positive lens L21, As opposed to the spherical surface which has the radius of curvature on the optical axis of the field of a positive lens L23 or a negative lens L24 The height from an optical axis is the diagonal length (mm) of the effective image pick-up field (abbreviation rectangle) of an image sensor, and the amount of aspheric surface deflections in 0.3L and L set amount Asp_{of} aspheric surface deflections $21F$ to 0, when the body side face of a positive lens L21 is the spherical surface.

[0168] [8] The zoom lens of the above 2-7 characterized by satisfying the following conditions (7) given in any 1 term.

[0169]

(7) $-0.5 < (R_{21F} - R_{22R}) / (R_{21F} + R_{22R}) < 0.3$ however R_{21F} , and R_{22R} It is the radius of curvature on the optical axis of the field by the side of the body of the positive lens L21 of the 2nd lens group, and the field by the side of the image of a negative lens L22, respectively.

[0170] [9] The zoom lens of the above 2-8 characterized by satisfying the following conditions (8) and (9) given in any 1 term.

[0171] (8) $-1 < f_3 / f_{2R} < 1.6$ (9) It corrects $0.02 < d_{22} / L < 0.5$. f_{2R} and f_3 , respectively The synthetic focal distance of the positive lens L23 of the 2nd lens group, and a negative lens L24, and the focal distance of the 3rd lens group, d_{22} is spacing of the image side face of the negative lens L22 of the 2nd lens group, and the body side face of a positive lens L23, and L is the diagonal length (mm) of the effective image pick-up field (abbreviation rectangle) of an image sensor.

[0172] [10] A zoom lens the above 1 which satisfies the following conditions (10) thru/or given in any 1 term of 9.

[0173] (10) $-1 < f_2 F / R_{21R} < 2.5$, however R_{21R} The radius of curvature of the field by the side of the image of the positive lens L21 of the 2nd lens group and $f_2 F$ are the synthetic focal distances of the positive lens L21 of the 2nd lens group, and a negative lens L22.

[0174] [11] It is the zoom lens of ten given in any 1 term from the above 1 characterized by said 3rd lens group moving to an image side by the locus of a convex in case variable power is carried out to a tele edge from a wide angle edge.

[0175] [12] The zoom lens of 11 given in any 1 term from the above 1 characterized by focusing by moving said 3rd lens group in accordance with an optical axis.

[0176] [13] Wide angle edge half field angle ω Zoom lens of 12 given in any 1 term from the above 1 characterized by being in the range of 27 to 42 degrees.

[0177] [14] Electronic image pick-up equipment characterized by having the zoom lens of 13 given in any 1 term from the above 1.

[0178]

[Effect of the Invention] The zoom lens which excelled [thickness / collapsing] in storability thinly, and excelled [scale factor / high] in the image formation engine performance also in the rear focus by this invention can be obtained, and it becomes possible to attain thorough thin shape-ization of a video camera or a digital camera.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] They are the wide angle edge at the time of the infinite distance object point focus of the example 1 of the zoom lens used for the electronic image pick-up equipment of this invention (a), an intermediate state (b), and a lens sectional view in a tele edge (c).

[Drawing 2] It is the same lens sectional view as drawing 1 of the zoom lens of an example 2.

[Drawing 3] It is the same lens sectional view as drawing 1 of the zoom lens of an example 3.

[Drawing 4] It is the same lens sectional view as drawing 1 of the zoom lens of an example 4.

[Drawing 5] It is the same lens sectional view as drawing 1 of the zoom lens of an example 5.

[Drawing 6] It is the same lens sectional view as drawing 1 of the zoom lens of an example 6.

[Drawing 7] It is the same lens sectional view as drawing 1 of the zoom lens of an example 7.

[Drawing 8] It is the same lens sectional view as drawing 1 of the zoom lens of an example 8.

[Drawing 9] It is the same lens sectional view as drawing 1 of the zoom lens of an example 9.

[Drawing 10] It is the same lens sectional view as drawing 1 of the zoom lens of an example 10.

[Drawing 11] It is an aberration Fig. at the time of the infinite distance object point focus of an example 1.

[Drawing 12] It is an aberration Fig. at the time of photographic subject distance the focus of 10cm of an example 1.

[Drawing 13] It is drawing for explaining the definition of the amount of aspheric surface deflections which can set this invention.

[Drawing 14] It is drawing for explaining the diagonal length of the effective image pick-up side in the case of taking a photograph with an electronic image sensor.

[Drawing 15] It is drawing showing the permeability property of an example of a near-infrared Sharp cut coat.

[Drawing 16] It is drawing showing the permeability property of an example of a color filter prepared in the injection side side of a low pass filter.

[Drawing 17] It is drawing showing color filter arrangement of a complementary color mosaic filter.

[Drawing 18] It is drawing showing an example of the wavelength property of a complementary color mosaic filter.

[Drawing 19] It is the front perspective view showing the appearance of the digital camera incorporating the zoom lens by this invention.

[Drawing 20] It is the back perspective view of the digital camera of drawing 19.

[Drawing 21] It is the sectional view of the digital camera of drawing 19.

[Description of Notations]

- G1 -- The 1st lens group
- G2 -- The 2nd lens group
- G3 -- The 3rd lens group
- S -- Aperture diaphragm
- IF -- Infrared cut absorption filter
- LF -- Low pass filter
- CG -- Cover glass
- I -- Image surface
- E -- Observer eyeball
- 40 -- Digital camera
- 41 -- Photography optical system
- 42 -- Optical path for photography
- 43 -- Finder optical system
- 44 -- Optical path for finders
- 45 -- Shutter
- 46 -- Flash plate
- 47 -- Liquid crystal display monitor
- 49 -- CCD
- 50 -- Covering member
- 51 -- Processing means
- 52 -- Record means
- 53 -- Object optical system for finders
- 55 -- Porro prism
- 57 -- Visual field frame
- 59 -- Eyepiece optical system

[Translation done.]

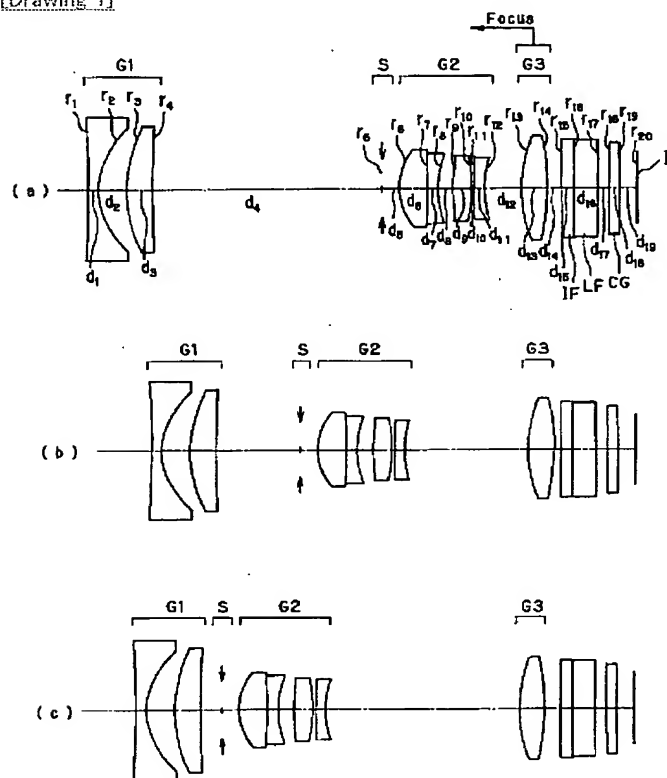
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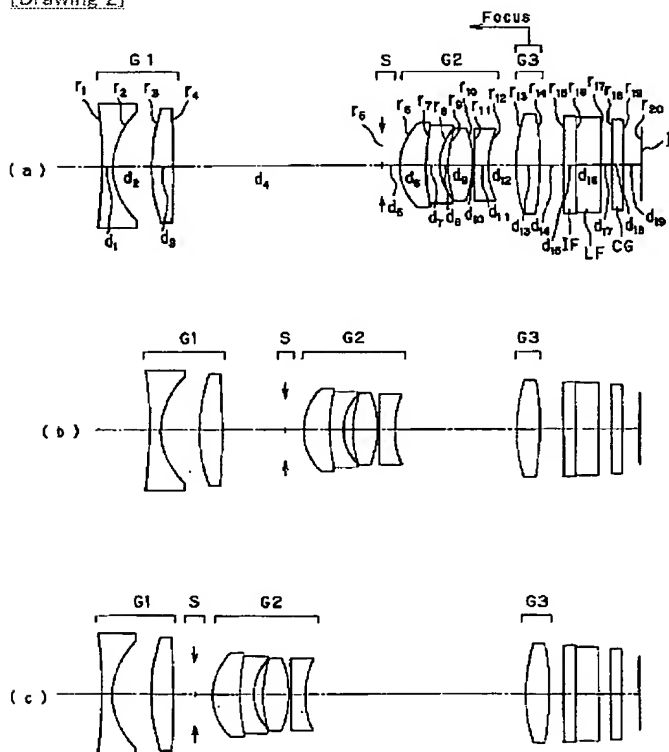
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- 2.*** shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

DRAWINGS

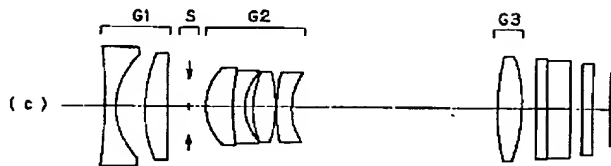
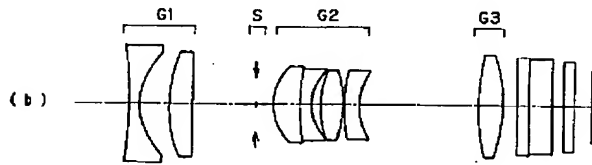
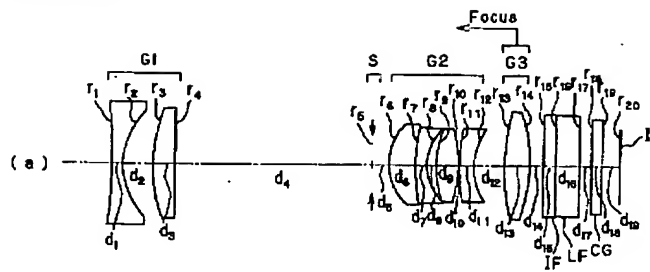
[Drawing 1]



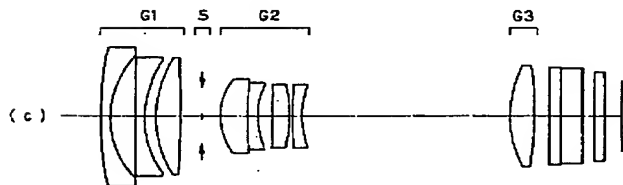
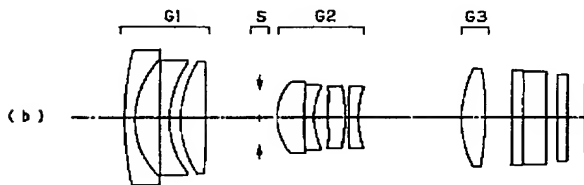
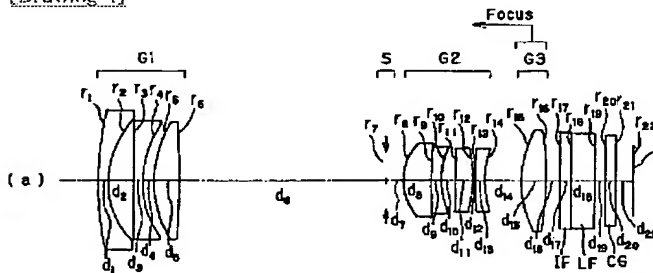
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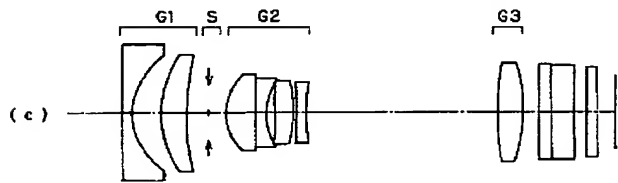
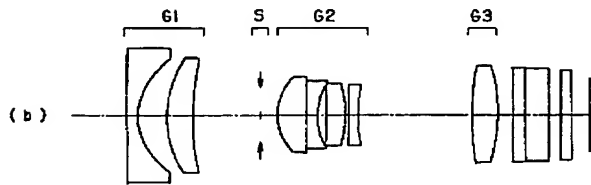
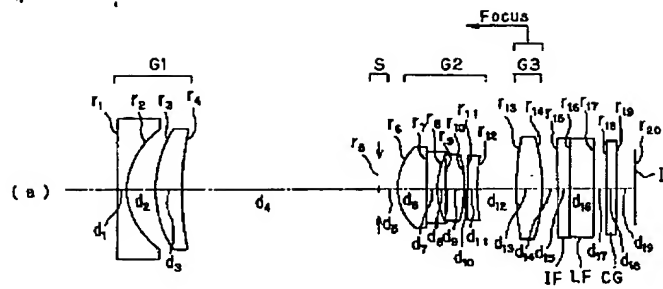
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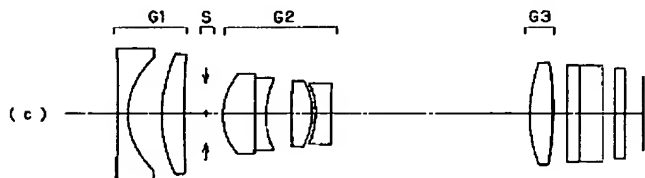
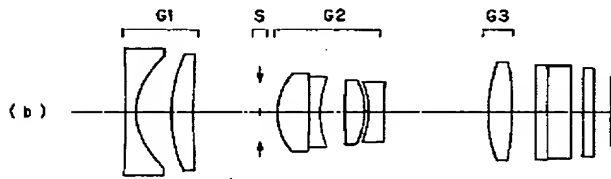
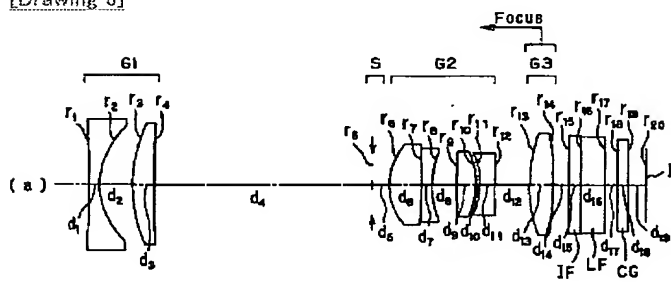
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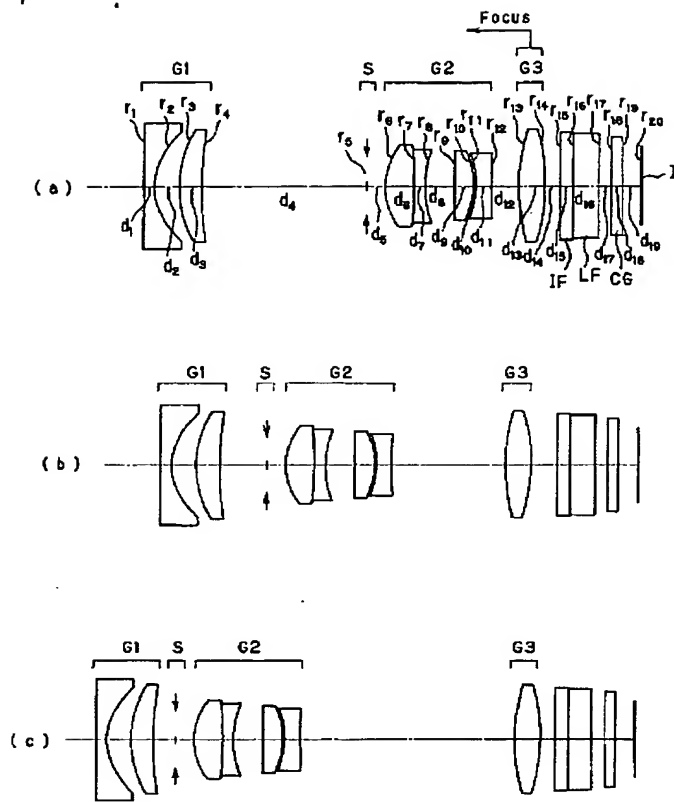
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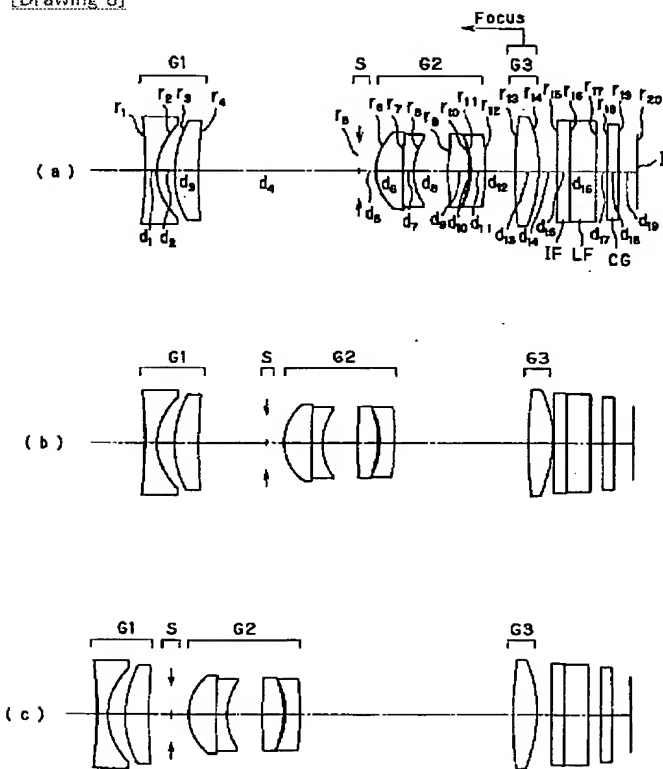
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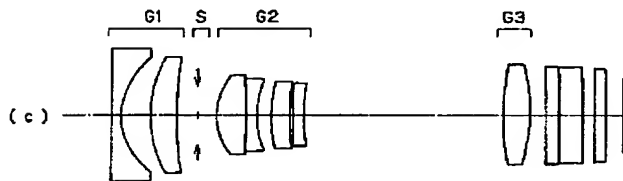
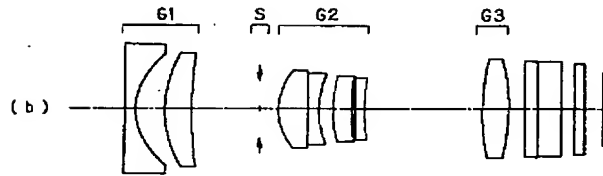
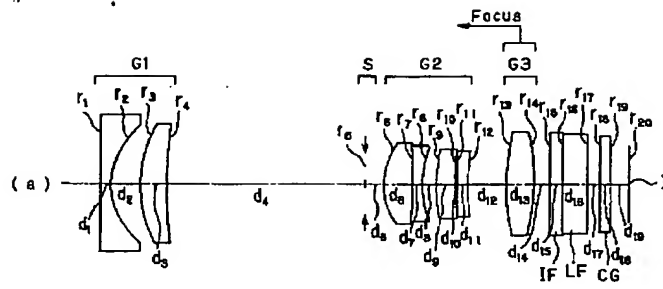
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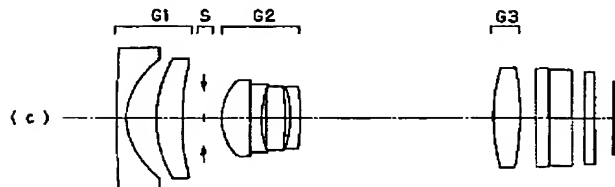
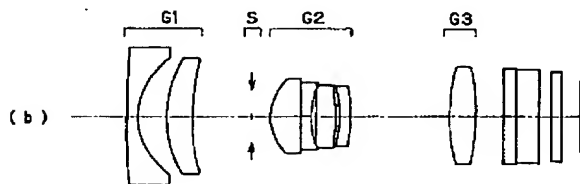
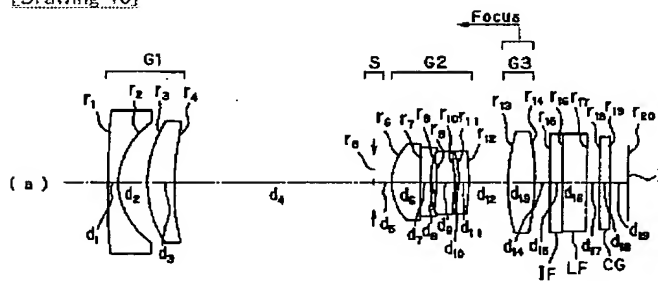
[Drawing 8]



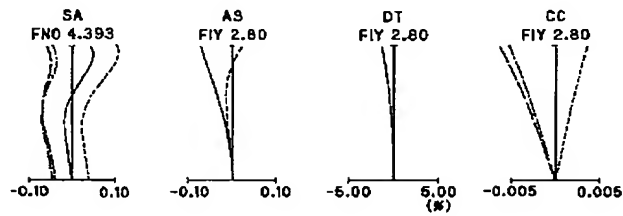
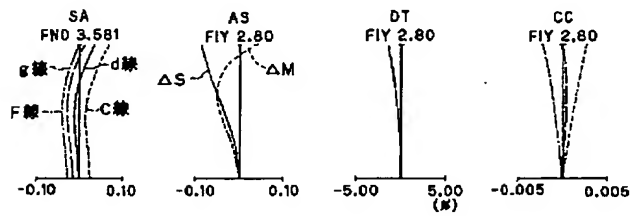
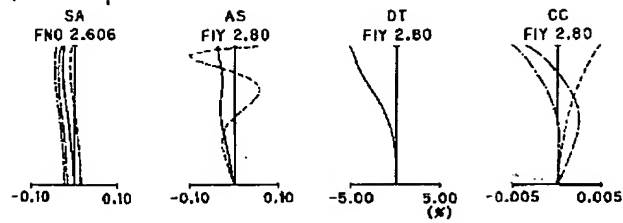
[Drawing 9]



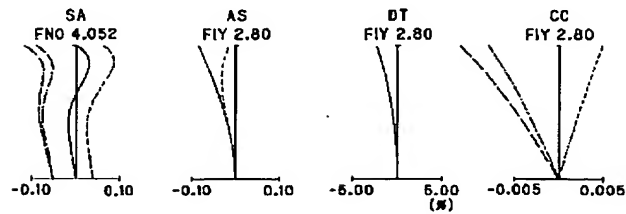
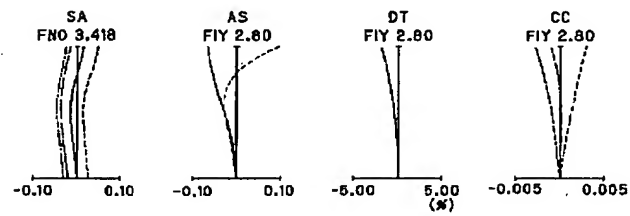
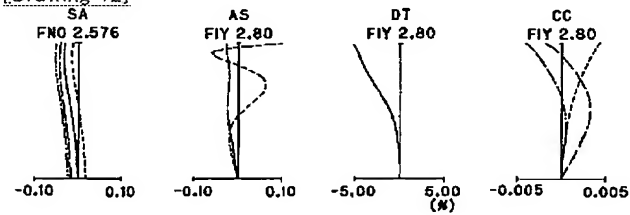
[Drawing 10]



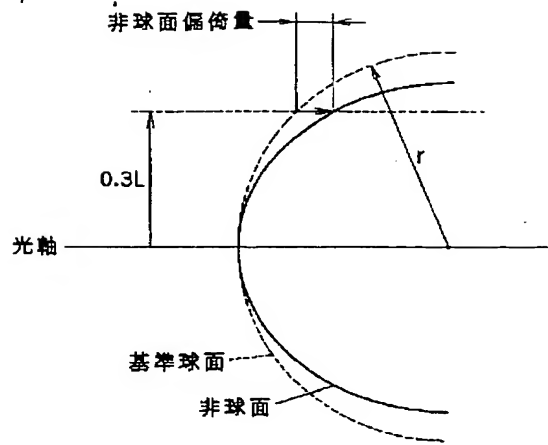
[Drawing 11]



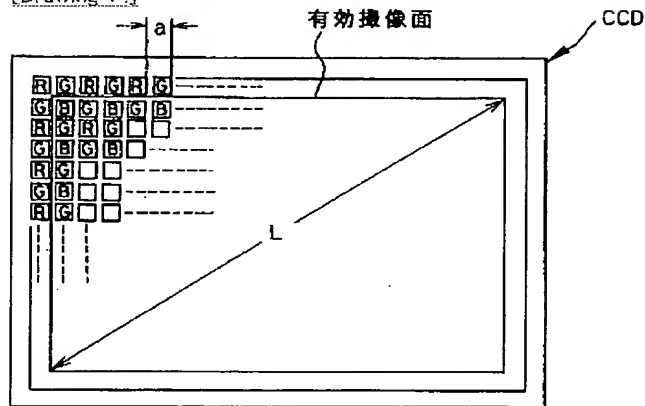
[Drawing 12]



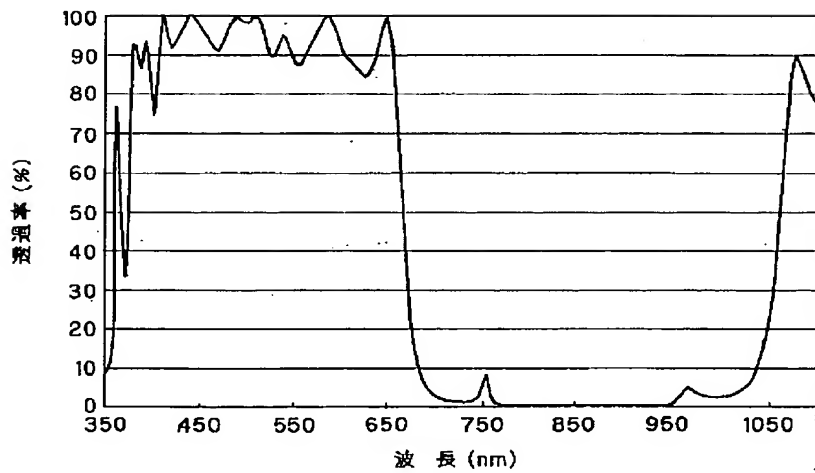
[Drawing 13]



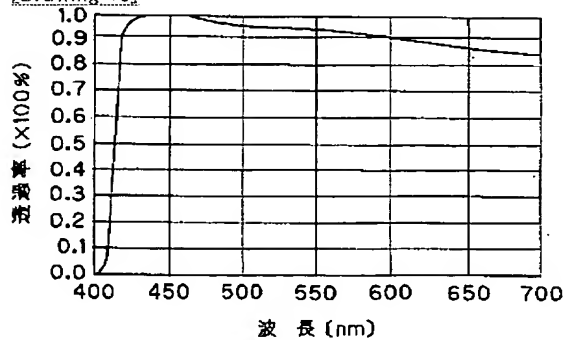
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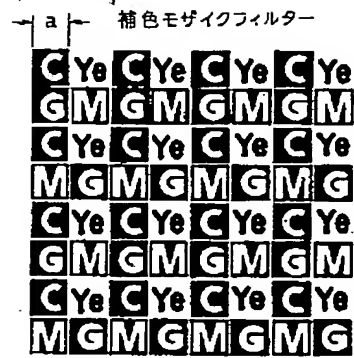
[Drawing 15]



[Drawing 16]

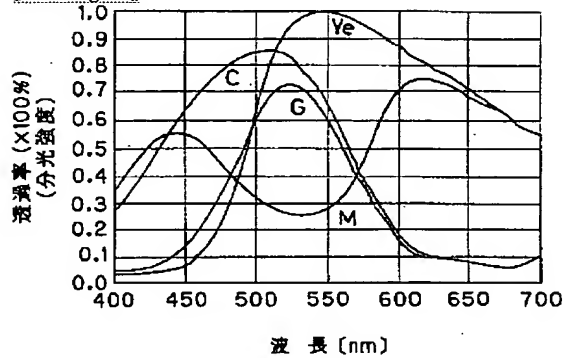


[Drawing 17]

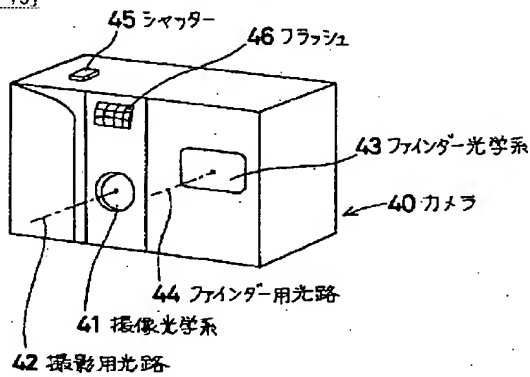


C:シアン M:マゼンタ
Ye:イエロー G:緑

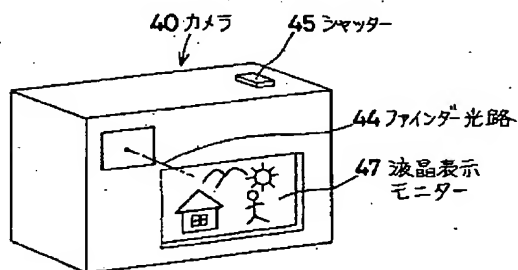
[Drawing 18]



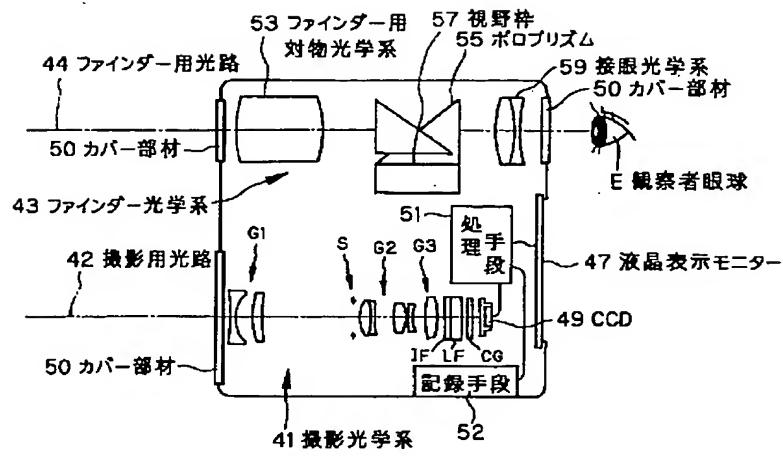
[Drawing 19]



[Drawing 20]



[Drawing 21]



[Translation done.]

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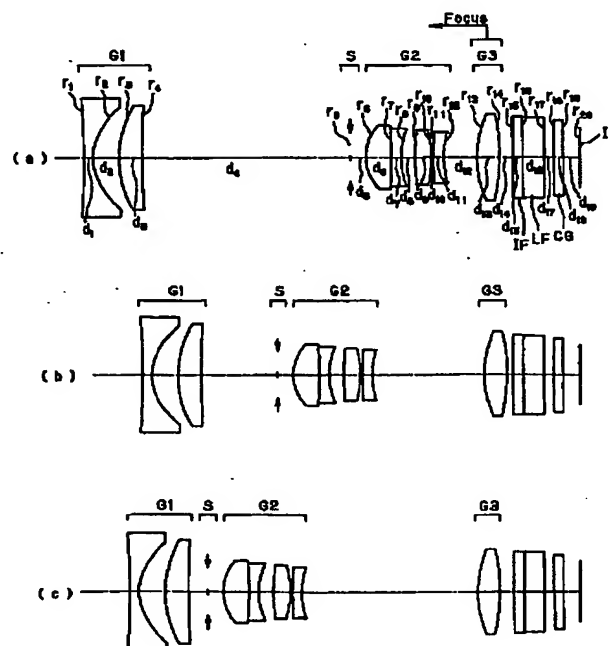
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(54) 【発明の名称】 ズームレンズ及びそれを有する電子撮像装置

(57) 【要約】

【課題】 構成枚数が少なく、小型で簡素にしやすく、高い結像性能を有するズーム方式を用いてビデオカメラやデジタルカメラの徹底的薄型化を図ること。

【解決手段】 負の第1群G1と、開口絞りSと、正の第2群G2と、正の第3群G3とからなり、広角端から望遠端への変倍に際して、第2群G2が物体側へのみ移動し、第3群G3が第2群G2との間隔を変化させつつ移動し、第2群G2は正レンズ、負レンズ、正レンズ、負レンズにて構成され、第2群G2中の像側の正レンズ又は負レンズの少なくとも何れかのレンズは非球面を有し、かつ、第2群G2の物体側の正レンズの物体側の面と、物体側の負レンズの像側の面の光軸上の曲率半径の比に関する条件(1)を満足する。



【特許請求の範囲】

【請求項1】 物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件(1)を満足することを特徴とするズームレンズ。

$$(1) \quad 0.6 < R_{22R} / R_{21F} < 2.2$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面、第2レンズ群の負レンズL22の像側の面の光軸上の曲率半径である。

【請求項2】 像側に配される電子撮像素子と一体化されたことを特徴とする請求項1記載ズームレンズ。

【請求項3】 電子撮像素子の撮像面側に配されるズームレンズにおいて、

前記ズームレンズは、物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件(2)、(3)、(4)を満足することを特徴とするズームレンズ。

$$(2) \quad 0 < (C_{24F} - C_{23R}) \cdot L < 1.6$$

$$(3) \quad 0.01 < d_{23} / L < 0.2$$

$$(4) \quad -0.4 < L / f_{2R} < 0.8$$

ただし、 $C_{23R} = 1 / R_{23R}$ 、 $C_{24F} = 1 / R_{24F}$ であり、ここで、 R_{23R} 、 R_{24F} はそれぞれ第2レンズ群の正レンズL23の像側の面、第2レンズ群の負レンズL24の物体側の面の光軸上の曲率半径、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)、 d_{23} は第2レンズ群の正レンズL23と負レンズL24との光軸上の空気間隔、 f_{2R} は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【請求項4】 請求項1から3の何れか1項記載のズームレンズを備えたことを特徴とする電子撮像装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、ズームレンズ及びそれを有する電子撮像装置に関し、特に、ズームレンズ

等の光学系部分の工夫により奥行き方向の薄型化を実現した、ビデオカメラやデジタルカメラ等の電子撮像装置あるいはズームレンズに関するものである。また、そのズームレンズはリアフォーカスを可能にらしめたものに関するものである。

【0002】

【従来の技術】 近年、銀塩35mmフィルム(通称ライカ版)カメラに代わる次世代カメラとしてデジタルカメラ(電子カメラ)が注目されてきている。さらに、それは業務用高機能タイプからポータブルな普及タイプまで幅広い範囲でいくつものカテゴリーを有するようになってきている。

【0003】 本発明においては、特にポータブルな普及タイプのカテゴリーに注目し、高画質を確保しながら奥行き方向の薄いビデオカメラ、デジタルカメラを実現する技術を提供することをねらっている。カメラの奥行き方向を薄くするのに最大のネックとなっているのは、光学系、特にズームレンズ系の最も物体側の面から撮像面までの厚みである。最近では、撮影時に光学系をカメラボディ内からせり出し携帯時に光学系をカメラボディ内に収納するいわゆる沈胴式鏡筒を採用することが主流になっている。

【0004】 しかしながら、使用するレンズタイプやフィルターによって光学系沈胴時の厚みが大きく異なる。特にズーム比やF値等、仕様を高く設定するには、最も物体側のレンズ群が正の屈折力を有するいわゆる正先行型ズームレンズは、各々のレンズエレメントの厚みやデッドスペースが大きく、沈胴してもたいして厚みが薄くならない(特開平11-258507号)。負先行型で特に2乃至3群構成のズームレンズはその点有利であるが、群内構成枚数が多かったり、エレメントの厚みが大きかったり、最も物体側のレンズが正レンズの場合も沈胴しても薄くならない(特開平11-52246号)。現在知られている中で電子撮像素子用に適しかつズーム比、画角、F値等を含めた結像性能が良好で沈胴厚を最も薄くできる可能性を有するものの例として、特開平11-287953号、特開2000-267009、特開2000-275520等のものがある。

【0005】 第1群を薄くするには入射瞳位置を浅くするのがよいが、そのためには第2群の倍率を高くすることになる。一方、そのために第2群の負担が大きくなりそれ自身を薄くすることが困難になるばかりでなく、収差補正の困難さや製造誤差の効きが増大し好ましくない。薄型化、小型化を実施するには、撮像素子を小さくすればよいが、同じ画素数とするためには画素ピッチを小さくする必要があり、感度不足を光学系でカバーしなければならない。回折の影響も然りである。

【0006】 また、奥行き方向の薄いカメラボディにするために、合焦時のレンズ移動を前群ではなくいわゆるリアフォーカスで行うのが駆動系のレイアウト上有効であ

る。すると、リアフォーカスを実施したときの収差変動が小さい光学系を選択する必要が出てくる。

【0007】

【発明が解決しようとする課題】本発明は従来技術のこのような状況に鑑みてなされたものであり、その目的は、構成枚数が少なく、リアフォーカス方式等機構レイアウト上小型で簡素にやすく、無限遠から近距離まで安定した高い結像性能を有するズーム方式あるいはズーム構成を選択し、さらには、ズームレンズの各レンズエレメントを薄くして各群の総厚を薄くしたり、フィルター類の選択をも考慮して、ビデオカメラやデジタルカメラの徹底的薄型化を図ることである。

【0008】

【課題を解決するための手段】上記目的を達成するために、本発明のズームレンズは、物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件(1)を満足することを特徴とするものである。

【0009】

$$(1) \quad 0.6 < R_{22R} / R_{21F} < 2.2$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面、第2レンズ群の負レンズL22の像側の面の光軸上の曲率半径である。

【0010】この場合、像側に配される電子撮像素子と一体化されていることが望ましい。

【0011】また、本発明のズームレンズは、電子撮像素子の撮像面側に配されるズームレンズにおいて、前記ズームレンズは、物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件(2)、(3)、(4)を満足することを特徴とするものである。

【0012】

$$(2) \quad 0 < (C_{24F} - C_{23R}) \cdot L < 1.6$$

$$(3) \quad 0.01 < d_{23} / L < 0.2$$

$$(4) \quad -0.4 < L / f_{2R} < 0.8$$

ただし、 $C_{23R} = 1 / R_{23R}$ 、 $C_{24F} = 1 / R_{24F}$ であり、ここで、 R_{23R} 、 R_{24F} はそれぞれ第2レンズ群の正レンズL23の像側の面、第2レンズ群の負レンズL24の物体側の面の光軸上の曲率半径、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)、 d_{23} は第2レンズ群の正レンズL23と負レンズL24との光軸上の空気間隔、 f_{2R} は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【0013】本発明は、これらのズームレンズを備えた電子撮像装置を含むものである。

【0014】以下、本発明において上記構成をとる理由と作用を説明する。

【0015】本発明において、物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時に広角端から望遠端への変倍を、第2レンズ群の物体側への単調な移動と、第3レンズ群の第2レンズ群とは異なる量の移動により行なうズームレンズにおいて、第2レンズ群が、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成したズームレンズを採用している。

【0016】なお、本発明において、レンズとは、単一の媒体からなるレンズを1単位とし、接合レンズは複数のレンズからなるものを意味する。

【0017】古くから銀塩フィルムカメラ用ズームレンズとしてよく使用される負正の2群ズームにおいて、それを小型化するために各焦点距離における正の後群(第2レンズ群)の倍率を高くするのがよいが、そのために、第2レンズ群のさらに像側に1枚の正レンズを第3レンズ群として加え、広角端から望遠端に変倍する際に第2レンズ群との間隔を変化させるという方法がよく知られている。また、この第3レンズ群はフォーカス用としても使用できる可能性を有している。そして、本発明の目的の達成、つまり、沈胴収納時のレンズ部総厚を薄くしてなおかつ第3レンズ群にてフォーカスをする際、非点収差を始めとする軸外収差の変動を抑制するために、第2レンズ群は、物体側から順に、正レンズと負レンズ及びこれに少なくとも正レンズを加えて構成することが必要不可欠要件で、さらに像側に負レンズを加えるといふ。

【0018】第3レンズ群にてフォーカスをする場合、収差変動が問題になるが、第3レンズ群に必要以上の量の非球面が入ると、その効果を出すために第1レンズ群・第2レンズ群で残存する非点収差を第3レンズ群にて補正することになり、ここで第3レンズ群がフォーカスのために動くと、そのバランスが崩れてしまい好ましくない。したがって、第3レンズ群でフォーカスする場合は、第1レンズ群・第2レンズ群で非点収差をズーム全域に亘り略取り切らねばならない。よって、第3レンズ

群は球面系又は少ない非球面量にて構成し、開口絞りを第2レンズ群の物体側に配し、第2レンズ群は、正レンズ、負レンズ、正レンズ、そして負レンズの順に構成するのがよい。また、このタイプでは前玉径が大きくなり難いので、開口絞りを第2レンズ群と一体（後記の本発明の実施例では、第2レンズ群の直前に配置し第2レンズ群と一体）とした方が、機構上単純であるばかりでなく、沈胴時のデッドスペースが発生し難く、広角端と望遠端のF値差が小さい。また、第2レンズ群の物体側の正レンズと負レンズはそれらの相対的偏心による収差の発生が著しいので、これらは接合レンズにした方がよい。接合にする場合は、できるだけ接合レンズ内（正レンズL21、負レンズL22）で収差をキャンセルして偏心敏感度を小さくするのがよい。

【0019】そこで、第2レンズ群の正レンズ21、負レンズL22に関して以下の条件式を満足するのがよい。

【0020】

$$(1) \quad 0.6 < R_{22R} / R_{21F} < 2.2$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面、第2レンズ群の負レンズL22の像側の面の光軸上の曲率半径である。

【0021】条件(1)の上限の2.2を越えると、全系収差の球面収差・コマ収差・非点収差の補正には有利だが、接合による偏心敏感度の緩和の効果が少ない。下限の0.6を越えると、全系収差の球面収差・コマ収差・非点収差の補正が困難になりやすい。

【0022】なお、以下のようにするとよりよい。

【0023】

$$(1-1) \quad 1.0 < R_{22R} / R_{21F} < 2.0$$

さらに、以下のようにすると最もよい。

【0024】

$$(1-2) \quad 1.4 < R_{22R} / R_{21F} < 1.8$$

さらに、第2レンズ群の正レンズL23と負レンズL24に関して、以下の条件式を満足するのがよい。

$$(2)' \quad 0.15 < (C_{24F} - C_{23R}) \cdot L < 1.3$$

$$(3)' \quad 0.01 < d_{23} / L < 0.15$$

$$(4)' \quad -0.3 < L / f_{2R} < 0.5$$

さらに、条件(2)～(4)の何れかあるいは複数を以下のようにするとさらによい。特に全てを以下のようにすると最もよい。

【0031】

$$(2)'' \quad 0.3 < (C_{24F} - C_{23R}) \cdot L < 1$$

$$(3)'' \quad 0.01 < d_{23} / L < 0.1$$

$$(4)'' \quad -0.2 < L / f_{2R} < 0.2$$

また、収差補正のための非球面レンズは、第1レンズ群に歪曲収差・非点収差・コマ収差補正のために1枚と、第2レンズ群に球面収差のために2枚の全系で合計3枚とするのがよい。それ以上入れても効果は少なく、コスト高になるだけである。

【0025】

$$(2) \quad 0 < (C_{24F} - C_{23R}) \cdot L < 1.6$$

$$(3) \quad 0.01 < d_{23} / L < 0.2$$

$$(4) \quad -0.4 < L / f_{2R} < 0.8$$

ただし、 $C_{23R} = 1/R_{23R}$ 、 $C_{24F} = 1/R_{24F}$ であり、ここで、 R_{23R} 、 R_{24F} はそれぞれ第2レンズ群の正レンズL23の像側の面、第2レンズ群の負レンズL24の物体側の面の光軸上の曲率半径、 L は撮像素子の有効撮像領域（略矩形）の対角長（mm）、 d_{23} は第2レンズ群の正レンズL23と負レンズL24との光軸上の空気間隔、 f_{2R} は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【0026】条件(2)の下限値の0を越えると、球面収差が発生しやすく、上限値の1.6を越えると、第1レンズ群に非球面を導入しても非点収差を補正しきれない。

【0027】本発明では、第2レンズ群の正レンズL23と負レンズL24を接合せずに、両者の隣接する面の形状を収差補正のために有効に使うことを目的としている。条件(3)の下限値の0.01を越えると、正レンズL23と負レンズL24の面干渉が有効径内にまで及びやすい。上限値の0.2を越えると、レンズ径が分厚くなりやすい。

【0028】条件(4)の下限値の-0.4を越えると、射出瞳位置が像面に接近しシェーディングを引き起こしやすく、また、正レンズL21と負レンズL22を接合とする場合、偏心敏感度は正レンズL21と負レンズL22に集中させる方が都合がよいため、その場合は、できれば正の値になるようにした方がよい。上限値の0.8を越えると、小型で高いズーム比を確保し難い。

【0029】なお、条件(2)～(4)の何れかあるいは複数を以下のようにするとよりよい。

【0030】

【0032】また、軸上色収差や倍率色収差補正について、以下の条件を満たすとよい。

【0033】

$$(5) \quad 2.5 < \nu_{21} - \nu_{22} + \nu_{23} - \nu_{24} < 5.5$$

ただし、 ν_{21} 、 ν_{22} 、 ν_{23} 、 ν_{24} はそれぞれ第2レンズ群の正レンズL21、負レンズL22、正レンズL23、負レンズL24の媒質のアッペ数（d線基準）である。

【0034】条件(5)の下限値2.5を越えると、軸上色収差・倍率色収差が補正不足になりやすく、上限値の5.5を越えると、これらが補正過剰になりやすい。

【0035】なお、以下のようにするとよりよい。

【0036】

$$(5)' \quad 2.5 < \nu_{21} - \nu_{22} + \nu_{23} - \nu_{24} < 5.0$$

さらに、以下のようにすると最もよい。

【0037】

$$(6) \quad 7.5 \times 10^{-3} \cdot L > | \text{Asp2R} | > | \text{Asp21F} |$$

ただし、Asp21F、Asp2R はそれぞれ正レンズL21の物体側の面、正レンズL23又は負レンズL24の面の光軸上での曲率半径を有する球面に対し、光軸からの高さが0.3Lでの非球面偏倚量、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)であり、正レンズL21の物体側面が球面の場合は非球面偏倚量Asp21Fを0とする。

【0039】すなわち、本発明でいう非球面偏倚量は、図13に示すように、対象とする非球面の光軸上での曲率半径rを有する球面(基準球面)に対し、電子撮像素子の有効撮像領域の対角長をLとすると、光軸からの高さが0.3Lの位置でのその非球面の偏倚量を言うも

$$(6)' \quad 5.0 \times 10^{-3} \cdot L > | \text{Asp2R} | > | \text{Asp21F} |$$

さらに、以下のようにすると最もよい。

$$(6)'' \quad 2.5 \times 10^{-3} \cdot L > | \text{Asp2R} | > | \text{Asp21F} |$$

別の条件として、以下を満たすとよりよい。

【0044】

$$(6-2) \quad | \text{Asp2R} | > 3 \cdot | \text{Asp21F} |$$

さらに、以下のようにすると最もよい。

【0045】

$$(7) \quad -0.5 < (R_{21F} - R_{22R}) / (R_{21F} + R_{22R}) < 0.3$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面と負レンズL22の像側の面の光軸上の曲率半径である。因みに、この条件式は通常のシェープファクターの逆数になっている。

【0047】この条件の下限の-0.5を越えると、球面収差補正不足になりやすく、レンズ厚みが厚くなりや

$$(7)' \quad -0.4 < (R_{21F} - R_{22R}) / (R_{21F} + R_{22R}) < 0.2$$

さらに、以下のようにすると最もよい。

$$(7)'' \quad -0.3 < (R_{21F} - R_{22R}) / (R_{21F} + R_{22R}) < 0.1$$

また、条件(2)系又は(7)系に対し、さらに以下の条件を(8)、(9)の何れかあるいは両方を満足すると、射出瞳位置つまりシェーディングに関して有利である。

$$【0051】(8) \quad -1 < f_s / f_{2R} < 1.6$$

$$(9) \quad 0.02 < d_{22} / L < 0.5$$

ただし、 f_{2R} と f_s はそれぞれ第2レンズ群の正レンズL23と負レンズL24との合成焦点距離と第3レンズ群の焦点距離、 d_{22} は第2レンズ群の負レンズL22の像側面と正レンズL23の物体側面との間隔、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)である。

【0052】条件(8)の上限値の1.6を越えると、広角端における射出瞳位置つまりシェーディングには有利であるが、望遠端に変倍する際の射出瞳位置の変動量

$$(5)'' \quad 3.0 < \nu_{21} - \nu_{22} + \nu_{23} - \nu_{24} < 5.0$$

次に、第2レンズ群の正レンズL23、負レンズL24の非球面について、以下の条件を満足するとよい。

【0038】

のである。

【0040】条件(6)のように、正レンズL23又は負レンズL24にある程度の非球面を導入しないと、球面収差・コマ収差・非点収差が十分に補正できない。正レンズL21より非球面度が少ないと、コマ収差・非点収差の補正が不十分となりやすい。その上限値の $7.5 \times 10^{-3} \cdot L$ を越えると、正レンズL23又は負レンズL24の偏心敏感度が大きくなりすぎ、部品精度や組み立て精度が厳しくなり好ましくない。なお、正レンズL21の物体側の面は球面でも構わない。

【0041】なお、以下のようにするとよりよい。

【0042】

【0043】

$$(6-3) \quad | \text{Asp2R} | > 6 \cdot | \text{Asp21F} |$$

また、条件(2)系に対し、さらに以下の条件を満足すると、球面収差の補正上よい。

【0046】

すい。また、物体側正レンズL21の加工性も悪化する。上限の0.3を越えると、逆に高次の球面収差が発生したり負レンズ側の深い凹面の加工性が悪化する。

【0048】なお、以下のようにするとよりよい。

【0049】

【0050】

が大きく、望遠端でのシェーディングにとって不利となる。下限値の-1を越えると、広角端での射出瞳が近すぎてシェーディングが発生しやすい点、第3レンズ群にてフォーカスをする際にその移動量が大きくなりすぎてスペース上の不利がある。また、近軸的に軸上光線の高い第2レンズ群の像側の正レンズを強くする必要があるため、第2レンズ群の主点位置が後ろへ移動し、高い倍率を得難く、第1レンズ群が巨大化しやすい。

【0053】条件(9)の下限の0.02を越えると、非点収差の補正と広角端での射出瞳位置の関係でシェーディングが発生しやすい。上限の0.5を越えると、第2レンズ群の厚みが厚く、沈胴厚の小さくするのに足枷となる。

【0054】なお、第2レンズ群の正レンズL21と負レンズL22をひとまとめにした部分群と正レンズL2

3と負レンズL24をひとまとめにした部分群との相対位置誤差の性能劣化に対する効きは小さい(ただし、その場合は正レンズL23の非球面量は小さめにするのが望ましい。)ので、変倍時や撮像時には一定の間隔あるいは変化する間隔を大きめに設け、沈胴時にのみ縮める構造にしてもよい。d₂₂を撮像時に大きめにすることは、周辺部の性能確保に有利である。

【0055】なお、条件(8)、(9)の何れかあるいは両方を以下のようにするとよりよい。

【0056】

$$(8)' \quad -0.7 < f_3 / f_{2R} < 1.0$$

$$(9)' \quad 0.04 < d_{22} / L < 0.4$$

さらに、条件(8)、(9)の何れかあるいは両方を以下のようにするとさらによい。特に両方を以下のようにすると最もよい。

【0057】

$$(8)'' \quad -0.4 < f_3 / f_{2R} < 0.4$$

$$(9)'' \quad 0.06 < d_{22} / L < 0.3$$

これとは別に、条件(2)又は(5)に対し、さらに以下の条件を満足すると沈胴時の小型化に有利である。

$$【0058】(10) \quad -1 < f_{2F} / R_{21R} < 2.5$$

ただし、R_{21R}は第2レンズ群の正レンズL21の像側の面の曲率半径、f_{2F}は第2レンズ群の正レンズL21と負レンズL22との合成焦点距離である。

【0059】条件(10)の上限の2.5を越えると、第2レンズ群の正レンズL21と負レンズL22のトータルの厚みを薄くしやすいが、軸上色収差の補正が困難になる。下限値の-1を越えると、軸上色収差の補正には有利だが、第2レンズ群の正レンズL21と負レンズL22のトータルの厚みを厚くせざるを得ず、沈胴厚を薄くするのに足枷となる。

【0060】なお、以下のようにするとよりよい。

【0061】

$$(12) \quad -1.0 < (R_{31} + R_{32}) / (R_{31} - R_{32}) < 1.2$$

ただし、R₃₁とR₃₂はそれぞれ第3レンズ群の正レンズの最も物体側と最も像側の面の曲率半径である。

【0069】条件(12)の上限値の1.2を越えると、リアフォーカスによる非点収差の変動が大きくなりすぎ、無限物点で非点収差を良好に補正し得ても、近距

$$(12)' \quad -0.3 < (R_{31} + R_{32}) / (R_{31} - R_{32}) < 1.2$$

さらに、以下のようにすると最もよい。

$$(12)'' \quad 0.0 < (R_{31} + R_{32}) / (R_{31} - R_{32}) < 1.0$$

以上、ズームレンズ部について沈胴厚を薄くしつつも、結像性能を良好にする手段を提供した。

【0073】なお、本発明のズームレンズは、広角域を含む電子撮像装置を構成する上で有利である。特に、広角端における対角方向の半面角 ω_w が以下の条件を満足する電子撮像装置に用いることが好ましい(後記の各実施例に記載の広角端半面角は ω_w に相当する。)

【0074】 $27^\circ < \omega_w < 42^\circ$ この条件の下限値の

$$(10)' \quad -0.8 < f_{2F} / R_{21R} < 0.8$$

さらに、以下のようにすると最もよい。

【0062】

$$(10)'' \quad -0.6 < f_{2F} / R_{21R} < 0.5$$

前記条件(2)系又は(7)系又は(10)系に対し、さらに以下の条件を満足すると、沈胴時の小型化に有利である。

$$【0063】(11) \quad -0.5 < f_2 / f_{2R} < 1$$

ただし、f₂は第2レンズ群全体の合成焦点距離、f_{2R}は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【0064】条件(11)は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離と第2レンズ群全体の合成焦点距離の比を規定したものである。上限の1を越えると、第2レンズ群の主点が像側寄りになるために第2レンズ群倍率を高くならず、第1レンズ群の移動量が大きくなったり大型化しやすいか、使用状態における第2レンズ群後方にデッドスペースができやすく、全長が長くなり、沈胴厚を薄くするために鏡枠機械構造が複雑になるか巨大化する。あるいは、あまり薄くできない。下限値の-0.5を越えると、非点収差の補正が困難となる。

【0065】なお、以下のようにするとよりよい。

【0066】

$$(11)' \quad -0.4 < f_2 / f_{2R} < 0.7$$

さらに、以下のようにすると最もよい。

【0067】

$$(11)'' \quad -0.3 < f_2 / f_{2R} < 0.4$$

また、第3レンズ群については、全てのレンズ面共略球面より構成するのがよいが、その際、形状的に以下の条件を満たすのがよい。

【0068】

離物点に対しては非点収差が悪化しやすい。下限値の-1.0を越えると、リアフォーカスによる非点収差変動は少ないが、無限物点に対する収差補正が困難となる。

【0070】なお、以下のようにするとよりよい。

【0071】

$$(12)' \quad -0.3 < (R_{31} + R_{32}) / (R_{31} - R_{32}) < 1.2$$

【0072】

$$(12)'' \quad 0.0 < (R_{31} + R_{32}) / (R_{31} - R_{32}) < 1.0$$

27° を越えて広角端半面角が狭くなると、収差補正上は有利になるが、実用的な広角端での画角ではなくなる。一方、上限値の 42° を越えると、歪曲収差、倍率の色収差が発生しやすくなり、レンズ枚数が増加する。

【0075】次に、フィルター類を薄くする件について言及する。電子撮像装置には、通常、赤外光が撮像面に入射しないように一定の厚みのある赤外吸収フィルターを撮像素子よりも物体側に挿入している。これを厚みの

ないコーティングに置き換えることを考える。当然その分薄くなる訳だが、副次的効果がある。ズームレンズ系後方にある撮像素子よりも物体側に、波長600nmでの透過率(τ_{600})が80%以上、700nmでの透過率(τ_{700})が8%以下の近赤外シャープカットコートを導入すると、吸収タイプよりも700nm以上の近赤外領域の透過率が低く、かつ、相対的に赤側の透過率が高くなり、補色モザイクフィルターを有するCCD等の固体撮像素子の欠点である青紫側のマゼンタ化傾向がゲイン調整により緩和され、原色フィルターを有するCCD等の固体撮像素子並みの色再現を得ることができる。

【0076】すなわち、

$$(13) \quad \tau_{600} / \tau_{550} \geq 0.8$$

$$(14) \quad \tau_{700} / \tau_{550} \leq 0.08$$

を満たすことが望ましい。ただし、 τ_{550} は波長550nmでの透過率である。

【0077】なお、条件(13)、(14)の何れかあるいは両方を以下のようにするとよりよい。

$$【0078】(13)' \quad \tau_{600} / \tau_{550} \geq 0.85$$

$$(14)' \quad \tau_{700} / \tau_{550} \leq 0.05$$

さらに、条件(13)、(14)の何れかあるいは両方を以下のようにするとさらによい。特に両方を以下のようにすると最もよい。

$$【0079】(13)'' \quad \tau_{600} / \tau_{550} \geq 0.9$$

$$(14)'' \quad \tau_{700} / \tau_{550} \leq 0.03$$

CCD等の固体撮像素子のもう1つの欠点は、近紫外域の波長550nmに対する感度が人間の目のそれよりもかなり高いことである。これも、近紫外域の色収差による画像のエッジ部の色にじみを目立たせている。特に光学系を小型化すると致命的である。したがって、波長400nmでの透過率(τ_{400})の550nmでのそれ(τ_{550})に対する比が0.08を下回り、440nmでの透過率(τ_{440})の550nmでのそれ(τ_{550})に対する比が0.4を上回るような吸収体あるいは反射体を光路上に挿入すれば、色再現に必要な波長域を失わず(良好な色再現を保ったまま)、色にじみなどのノイズがかなり軽減される。

【0080】すなわち、

$$(15) \quad \tau_{400} / \tau_{550} \leq 0.08$$

$$(16) \quad \tau_{440} / \tau_{550} \geq 0.4$$

を満たすことが望ましい。

【0081】なお、条件(15)、(16)の何れかあるいは両方を以下のようにするとよりよい。

$$【0082】(15)' \quad \tau_{400} / \tau_{550} \leq 0.06$$

$$(16)' \quad \tau_{440} / \tau_{550} \geq 0.5$$

さらに、条件(15)、(16)の何れかあるいは両方を以下のようにするとさらによい。特に両方を以下のようにすると最もよい。

$$【0083】(15)'' \quad \tau_{400} / \tau_{550} \leq 0.04$$

$$(16)'' \quad \tau_{440} / \tau_{550} \geq 0.6$$

なお、これらのフィルターの設置場所は結像光学系と撮像素子の間がよい。

【0084】一方、補色フィルターの場合、その透過光エネルギーの高さから、原色フィルター付きCCDと比べ実質的感度が高く、かつ、解像的にも有利であるため、小型CCDを使用したときのメリットが大である。もう一方のフィルターである光学的ローパスフィルターについても、その総厚 t_{LPP} (mm)が以下の条件を満たすようにするとよい。

【0085】

$$(17) \quad 0.15 < t_{LPP} / a < 0.45$$

ただし、 a は撮像素子の水平画素ピッチ(単位 μm)であり、 $5 \mu m$ 以下である。

【0086】沈胴厚を薄くするには、光学的ローパスフィルターを薄くすることも効果的であるが、一般的にはモアレ抑制効果が減少して好ましくない。一方、画素ピッチが小さくなるにつれて結像レンズ系の回折の影響により、ナイキスト限界以上の周波数成分のコントラストは減少し、モアレ抑制効果の現象はある程度許容されるようになる。例えば、像面上投影時の方位角度が水平($=0^\circ$)と $\pm 45^\circ$ 方向にそれぞれ結晶軸を有する3種類のフィルターを光軸方向に重ねて使用する場合、かなりモアレ抑制効果があることが知られている。この場合のフィルターが最も薄くなる仕様としては、水平に $a \mu m$ 、 $\pm 45^\circ$ 方向にそれぞれ $\text{SQRT}(1/2) * a \mu m$ だけずらせるものが知られている。このときのフィルター厚は、凡そ $[1 + 2 * \text{SQRT}(1/2)] * a / 5.88$ (mm)となる。ここで、 SQRT はスクエアルートであり平方根を意味する。これは、丁度ナイキスト限界に相当する周波数においてコントラストをゼロにする仕様である。これよりは数%乃至数十%程度薄くすると、ナイキスト限界に相当する周波数のコントラストが少し出てくるが、上記回折の影響で抑えることが可能になる。

【0087】上記以外のフィルター仕様、例えば2枚重ねあるいは1枚で実施する場合も含めて、条件(17)を満足するのがよい。その上限値の0.45を越えると、光学的ローパスフィルターが厚すぎ薄型化の妨げになる。下限値の0.15を越えると、モアレ除去が不十分になる。ただし、これを実施する場合の a の条件は $5 \mu m$ 以下である。

【0088】 a が $4 \mu m$ 以下なら、より回折の影響を受けやすいので

$$(17)' \quad 0.13 < t_{LPP} / a < 0.42$$

としてもよい。

【0089】また、水平画素ピッチと重なるローパスフィルターの枚数に応じて、以下のようにしてもよい。

$$【0090】(17)'' \quad 0.3 < t_{LPP} / a < 0.4$$

ただし、3枚重ねかつ $4 \leq a < 5$ (μm)のとき、 $0.2 < t_{LPP} / a < 0.28$

ただし、2枚重ねかつ $4 \leq a < 5$ (μm)のとき、

0. $1 < t_{LFF} / a < 0.16$

ただし、1枚のみかつ $4 \leq a < 5$ (μm) のとき、

0. $0.25 < t_{LFF} / a < 0.37$

ただし、3枚重ねかつ $a < 4$ (μm) のとき、

0. $0.16 < t_{LFF} / a < 0.25$

ただし、2枚重ねかつ $a < 4$ (μm) のとき、

0. $0.08 < t_{LFF} / a < 0.14$

ただし、1枚のみかつ $a < 4$ (μm) のとき。

【0091】画素ピッチの小さな電子撮像素子を使用する場合、絞り込みによる回折効果の影響で画質が劣化する。したがって、開口サイズが固定の複数の開口を有し、その中の1つを第1レンズ群の最も像側のレンズ面と第3レンズ群の最も物体側のレンズ面の間の何れかの光路内に挿入でき、かつ、他の開口と交換可能とすることで像面照度の調節することができる電子撮像装置としておき、その複数の開口の中、一部の開口内に550nmに対する透過率がそれぞれ異なり、かつ、80%未満であるような媒体を有するようにして光量調節を行なうのがよい。あるいは、 a (μm) / Fナンバー < 0.4 となるようなF値に相当する光量になるように調節を実施する場合は、開口内に550nmに対する透過率がそれぞれ異なりかつ80%未満の媒体を有する電子撮像装置とするのがよい。例えば、開放値から上記条件の範囲外ではその媒体なしあるいは550nmに対する透過率が91%以上のダミー媒質としておき、範囲内のときは回折の影響が出る程に開口絞り径を小さくするのではなく、NDフィルターのようなもので光量調節するのがよい。

【0092】また、その複数の開口をそれぞれ径をF値に反比例して小さくしたものにして揃えておき、NDフィルターの代わりにそれぞれ周波数特性の異なる光学的ローパスフィルターを開口内に入れておくのでもよい。絞り込むにつれて回折劣化が大きくなるので、開口径が小さくなる程光学的ローパスフィルターの周波数特性を高く設定しておく。

【0093】

【発明の実施の形態】以下、本発明の電子撮像装置に用いられるズームレンズの実施例1~10について説明する。実施例1~10の無限遠物点合焦時の広角端

(a)、中間状態(b)、望遠端(c)でのレンズ断面図をそれぞれ図1~図10に示す。各図中、第1レンズ群はG1、絞りはS、第2レンズ群はG2、第3レンズ群はG3、赤外カット吸収フィルターはIF、ローパスフィルターはLF、電子撮像素子であるCCDのカバーガラスはCG、CCDの像面はIで示してある。なお、赤外カット吸収フィルターIFに代えて、透明平板の入射面に近赤外シャープカットコートとしたものを用いてもよいし、ローパスフィルターLFに直接近赤外シャープカットコートを施してもよい。

【0094】実施例1のズームレンズは、図1に示すよ

うに、両凹負レンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、両凸正レンズと両凹負レンズの接合レンズと、両凸正レンズと、物体側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は像面側に凸の軌跡を描いて移動し、望遠端では広角端より物体側の位置になる。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0095】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0096】実施例2のズームレンズは、図2に示すように、両凹負レンズと、両凸正レンズとからなる負屈折力の第1レンズ群G1、開口絞りS、物体側に凸の正メニスカスレンズと物体側に凸の負メニスカスレンズの接合レンズと、両凸正レンズと、両凹負レンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端と広角端では略同じ位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は像面側に移動する。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0097】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0098】実施例3のズームレンズは、図3に示すように、両凹負レンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、物体側に凸の正メニスカスレンズと物体側に凸の負メニスカスレンズの接合レンズと、両凸正レンズと、物体側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端と広角端では略同じ位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は固定である。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0099】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体

側の面、両凸正レンズの物体側の面の3面に用いられている。

【0100】実施例4のズームレンズは、図4に示すように、物体側に凸の負メニスカスレンズ2枚と、両凸正レンズとからなる負屈折力の第1レンズ群G1、開口絞りS、物体側に凸の正メニスカスレンズと物体側に凸の負メニスカスレンズの接合レンズと、両凸正レンズと、物体側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に凸の軌跡を描いて移動し、望遠端では広角端より物体側の位置になる。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0101】非球面は、第1レンズ群G1の物体側の負メニスカスレンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0102】実施例5のズームレンズは、図5に示すように、物体側に凸の負メニスカスレンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、凸平正レンズと平凹負レンズの接合レンズと、両凸正レンズと、両凹負レンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に移動する。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0103】非球面は、第1レンズ群G1の負メニスカスレンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0104】実施例6のズームレンズは、図6に示すように、両凹負レンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、両凸正レンズと両凹負レンズの接合レンズと、両凸正レンズと、両凹負レンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に凸の軌跡を描いて移動し、望遠端では広角端より像面側の位置になる。近距離の被写体

にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0105】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0106】実施例7のズームレンズは、図7に示すように、両凹負レンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、両凸正レンズと両凹負レンズの接合レンズと、両凸正レンズと、両凹負レンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より物体側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に凸の軌跡を描いて移動し、望遠端と広角端では同じ位置になる。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0107】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0108】実施例8のズームレンズは、図8に示すように、両凹負レンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、物体側に凸の正メニスカスレンズと物体側に凸の負メニスカスレンズの接合レンズと、両凸正レンズと、像面側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より物体側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は像面側に凸の軌跡を描いて移動し、望遠端では広角端より像面側の位置になる。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0109】非球面は、第1レンズ群G1の両凹負レンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの物体側の面の3面に用いられている。

【0110】実施例9のズームレンズは、図9に示すように、物体側に凸の負メニスカスレンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、凸平正レンズと平凹負レンズの接合レンズと、両凸正レンズと、物体側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3から

なり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に移動する。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0111】非球面は、第1レンズ群G1の負メニスカスレンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、両凸正レンズの像面側の面の3面に用いられている。

【0112】実施例10のズームレンズは、図10に示すように、物体側に凸の負メニスカスレンズと、物体側に凸の正メニスカスレンズとからなる負屈折力の第1レンズ群G1、開口絞りS、物体側に凸の正メニスカスレンズと物体側に凸の負メニスカスレンズの接合レンズと、像面側に凸の正メニスカスレンズと、像面側に凸の負メニスカスレンズとからなる正屈折力の第2レンズ群G2、両凸正レンズ1枚からなる正屈折力の第3レンズ群G3からなり、広角端から望遠端に変倍する際は、第1レンズ群G1は物体側に凹の軌跡を描いて移動し、望遠端では広角端より像面側の位置になり、第2レンズ群G2は開口絞りSと一体に物体側に移動し、第3レンズ群G3は物体側に凸の軌跡を描いて移動し、望遠端では

広角端より物体側の位置になる。近距離の被写体にフォーカシングするために、第3レンズ群G3は物体側に繰り出される。

【0113】非球面は、第1レンズ群G1の負メニスカスレンズの像面側の面、第2レンズ群G2の接合レンズの物体側の面、単独の正メニスカスレンズの像面側の面の3面に用いられている。

【0114】以下に、上記各実施例の数値データを示すが、記号は上記の外、fは全系焦点距離、 ω は半画角、F_{NO}はFナンバー、WEは広角端、STは中間状態、TEは望遠端、 r_1 、 r_2 …は各レンズ面の曲率半径、 d_1 、 d_2 …は各レンズ面間の間隔、 n_{d1} 、 n_{d2} …は各レンズのd線の屈折率、 v_{d1} 、 v_{d2} …は各レンズのアッベ数である。なお、非球面形状は、xを光の進行方向を正とした光軸とし、yを光軸と直交する方向にとると、下記の式にて表される。

$$【0115】x = (y^2 / r) / [1 + \{1 - (K + 1)(y/r)^2\}^{1/2}] + A_4 y^4 + A_6 y^6 + A_8 y^8 + A_{10} y^{10}$$

ただし、rは近軸曲率半径、Kは円錐係数、 A_4 、 A_6 、 A_8 、 A_{10} はそれぞれ4次、6次、8次、10次の非球面係数である。

【0116】

実施例1

$r_1 = -102.7129$	$d_1 = 0.7000$	$n_{d1} = 1.80610$	$v_{d1} = 40.92$
$r_2 = 5.3602$ (非球面)	$d_2 = 2.0000$		
$r_3 = 11.4378$	$d_3 = 1.8000$	$n_{d2} = 1.84666$	$v_{d2} = 23.78$
$r_4 = 98.3090$	$d_4 =$ (可変)		
$r_5 = \infty$ (絞り)	$d_5 = 1.2000$		
$r_6 = 4.9724$ (非球面)	$d_6 = 2.0000$	$n_{d3} = 1.80610$	$v_{d3} = 40.92$
$r_7 = -64.0363$	$d_7 = 0.7000$	$n_{d4} = 1.84666$	$v_{d4} = 23.78$
$r_8 = 7.0009$	$d_8 = 1.1549$		
$r_9 = 15.2680$ (非球面)	$d_9 = 1.3000$	$n_{d5} = 1.69350$	$v_{d5} = 53.21$
$r_{10} = -12.7034$	$d_{10} = 0.1500$		
$r_{11} = 91.7989$	$d_{11} = 0.7000$	$n_{d6} = 1.80100$	$v_{d6} = 34.97$
$r_{12} = 8.2347$	$d_{12} =$ (可変)		
$r_{13} = 11.7154$	$d_{13} = 1.8000$	$n_{d7} = 1.48749$	$v_{d7} = 70.23$
$r_{14} = -20.5935$	$d_{14} =$ (可変)		
$r_{15} = \infty$	$d_{15} = 0.8000$	$n_{d8} = 1.51633$	$v_{d8} = 64.14$
$r_{16} = \infty$	$d_{16} = 1.5000$	$n_{d9} = 1.54771$	$v_{d9} = 62.84$
$r_{17} = \infty$	$d_{17} = 0.8000$		
$r_{18} = \infty$	$d_{18} = 0.7500$	$n_{d10} = 1.51633$	$v_{d10} = 64.14$
$r_{19} = \infty$	$d_{19} = 1.2097$		
$r_{20} = \infty$ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -9.1908 \times 10^{-4}$$

$$A_6 = 1.0097 \times 10^{-5}$$

$$A_8 = -1.5014 \times 10^{-8}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -1.4735 \times 10^{-4}$$

$$A_6 = 1.6281 \times 10^{-5}$$

$$A_8 = -7.9774 \times 10^{-7}$$

$$A_{10} = 0.0000$$

第9面

$$K = 0$$

$$A_4 = -2.0216 \times 10^{-3}$$

$$A_6 = -1.8880 \times 10^{-4}$$

$$A_8 = 9.7090 \times 10^{-6}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.50523	8.68872	12.89933
F_{No}	2.6065	3.5812	4.3925
ω (°)	33.2	18.1	12.4
d_4	15.98285	5.88144	1.50000
d_{12}	2.53628	8.66957	13.53479
d_{14}	0.92173	0.42989	0.99810

【0117】

実施例2

$r_1 = -40.0207$	$d_1 = 0.7000$	$n_{d1} = 1.80610$	$\nu_{d1} = 40.92$
$r_2 = 4.8393$ (非球面)	$d_2 = 2.7104$		
$r_3 = 14.6390$	$d_3 = 1.5606$	$n_{d2} = 1.84666$	$\nu_{d2} = 23.78$
$r_4 = -100.9877$	$d_4 =$ (可変)		
$r_5 = \infty$ (絞り)	$d_5 = 1.2000$		
$r_6 = 4.5526$ (非球面)	$d_6 = 1.8758$	$n_{d3} = 1.80610$	$\nu_{d3} = 40.92$
$r_7 = 15.8025$	$d_7 = 0.9429$	$n_{d4} = 1.84666$	$\nu_{d4} = 23.78$
$r_8 = 4.0750$	$d_8 = 0.6028$		
$r_9 = 7.1659$ (非球面)	$d_9 = 1.8221$	$n_{d5} = 1.69350$	$\nu_{d5} = 53.21$
$r_{10} = -8.0623$	$d_{10} = 0.1000$		
$r_{11} = \infty$	$d_{11} = 1.0000$	$n_{d6} = 1.80100$	$\nu_{d6} = 34.97$
$r_{12} = 6.7380$	$d_{12} =$ (可変)		
$r_{13} = 13.4670$	$d_{13} = 1.6540$	$n_{d7} = 1.48749$	$\nu_{d7} = 70.23$
$r_{14} = -21.9112$	$d_{14} =$ (可変)		
$r_{15} = \infty$	$d_{15} = 0.8000$	$n_{d8} = 1.51633$	$\nu_{d8} = 64.14$
$r_{16} = \infty$	$d_{16} = 1.5000$	$n_{d9} = 1.54771$	$\nu_{d9} = 62.84$
$r_{17} = \infty$	$d_{17} = 0.8000$		
$r_{18} = \infty$	$d_{18} = 0.7500$	$n_{d10} = 1.51633$	$\nu_{d10} = 64.14$
$r_{19} = \infty$	$d_{19} = 1.2000$		
$r_{20} = \infty$ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -1.6364 \times 10^{-3}$$

$$A_6 = 1.1356 \times 10^{-5}$$

$$A_8 = -2.5627 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -3.9899 \times 10^{-4}$$

$$A_6 = -2.2843 \times 10^{-5}$$

$$A_8 = -1.2585 \times 10^{-6}$$

$$A_{10} = -9.0236 \times 10^{-9}$$

第9面

$$K = 0$$

$$A_4 = -1.7288 \times 10^{-3}$$

$$A_6 = 4.6545 \times 10^{-5}$$

$$A_8 = -3.7671 \times 10^{-6}$$

$$A_{10} = 3.6071 \times 10^{-7}$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.20000	8.59999	12.80032
F _{No}	2.4980	3.5636	4.6676
ω (°)	35.2	18.3	12.4
d ₄	14.39292	4.31686	1.50000
d ₁₂	1.90425	8.66884	15.45557
d ₁₄	1.56049	1.52138	0.90000

【0118】

実施例3

r ₁ = -41.7871	d ₁ = 0.7000	n _{d1} = 1.80610	ν _{d1} = 40.92
r ₂ = 4.8061 (非球面)	d ₂ = 2.1538		
r ₃ = 11.7830	d ₃ = 1.5885	n _{d2} = 1.84666	ν _{d2} = 23.78
r ₄ = 498.8711	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.4711 (非球面)	d ₆ = 1.8148	n _{d3} = 1.80610	ν _{d3} = 40.92
r ₇ = 16.1235	d ₇ = 0.8513	n _{d4} = 1.84666	ν _{d4} = 23.78
r ₈ = 4.0848	d ₈ = 0.5201		
r ₉ = 6.1325 (非球面)	d ₉ = 1.6063	n _{d5} = 1.69350	ν _{d5} = 53.21
r ₁₀ = -11.1687	d ₁₀ = 0.1000		
r ₁₁ = 16.3851	d ₁₁ = 1.0000	n _{d6} = 1.80100	ν _{d6} = 34.97
r ₁₂ = 4.8782	d ₁₂ = (可変)		
r ₁₃ = 17.5725	d ₁₃ = 1.7579	n _{d7} = 1.48749	ν _{d7} = 70.23
r ₁₄ = -13.0293	d ₁₄ = 0.9000		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν _{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν _{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν _{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.2001		
r ₂₀ = ∞ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -1.5240 \times 10^{-3}$$

$$A_6 = 7.1028 \times 10^{-5}$$

$$A_8 = -2.5635 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

K = 0

 $A_4 = -4.1354 \times 10^{-4}$ $A_6 = -2.4486 \times 10^{-5}$ $A_8 = -1.4312 \times 10^{-6}$ $A_{10} = 3.7941 \times 10^{-8}$

第9面

K = 0

 $A_4 = -1.7166 \times 10^{-3}$ $A_6 = 5.3328 \times 10^{-5}$ $A_8 = -4.9514 \times 10^{-6}$ $A_{10} = -5.3554 \times 10^{-8}$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.20005	8.60008	12.80003
F _{No}	2.6418	3.7743	4.8647
ω (°)	35.2	18.3	12.5
d ₄	13.62386	4.39163	1.50000
d ₁₂	2.13358	8.33646	14.25744

【0119】

実施例4

r ₁ = 27.0909	d ₁ = 0.7000	n _{d1} = 1.80610	v _{d1} = 40.92
r ₂ = 6.6293 (非球面)	d ₂ = 1.8000		
r ₃ = 144.3405	d ₃ = 0.7000	n _{d2} = 1.80100	v _{d2} = 34.97
r ₄ = 8.3285	d ₄ = 0.8000		
r ₅ = 9.3403	d ₅ = 1.8000	n _{d3} = 1.80518	v _{d3} = 25.42
r ₆ = -172.3059	d ₆ = (可変)		
r ₇ = ∞ (絞り)	d ₇ = 1.2000		
r ₈ = 4.6685 (非球面)	d ₈ = 2.0000	n _{d4} = 1.80610	v _{d4} = 40.92
r ₉ = 39.3390	d ₉ = 0.7000	n _{d5} = 1.84666	v _{d5} = 23.78
r ₁₀ = 6.3668	d ₁₀ = 1.0180		
r ₁₁ = 21.8104 (非球面)	d ₁₁ = 1.3000	n _{d6} = 1.69350	v _{d6} = 53.21
r ₁₂ = -13.5364	d ₁₂ = 0.1500		
r ₁₃ = 38.5671	d ₁₃ = 0.7000	n _{d7} = 1.80518	v _{d7} = 25.42
r ₁₄ = 8.0481	d ₁₄ = (可変)		
r ₁₅ = 9.5072	d ₁₅ = 1.8000	n _{d8} = 1.48749	v _{d8} = 70.23
r ₁₆ = -24.4883	d ₁₆ = (可変)		
r ₁₇ = ∞	d ₁₇ = 0.8000	n _{d9} = 1.51633	v _{d9} = 64.14
r ₁₈ = ∞	d ₁₈ = 1.5000	n _{d10} = 1.54771	v _{d10} = 62.84
r ₁₉ = ∞	d ₁₉ = 0.8000		
r ₂₀ = ∞	d ₂₀ = 0.7500	n _{d11} = 1.51633	v _{d11} = 64.14
r ₂₁ = ∞	d ₂₁ = 1.2108		
r ₂₂ = ∞ (像面)			

非球面係数

第2面

K = 0

 $A_4 = -2.9630 \times 10^{-4}$ $A_6 = 4.2847 \times 10^{-5}$ $A_8 = -3.6003 \times 10^{-7}$ $A_{10} = 0.0000$

第8面

$$K = 0$$

$$A_4 = -2.6881 \times 10^{-4}$$

$$A_6 = 2.5560 \times 10^{-5}$$

$$A_8 = -3.5822 \times 10^{-7}$$

$$A_{10} = 0.0000$$

第11面

$$K = 0$$

$$A_4 = -2.1333 \times 10^{-3}$$

$$A_6 = -2.4378 \times 10^{-4}$$

$$A_8 = 3.2564 \times 10^{-7}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.48846	8.69183	12.90297
F _{No}	2.5989	3.4016	4.5450
ω (°)	33.4	18.4	12.5
d _e	14.80359	3.81650	1.50000
d ₁₄	2.53628	7.33575	14.91963
d ₁₈	0.92173	1.86494	0.99412

【0120】

実施例5

r ₁ = 208.2759	d ₁ = 0.7000	n _{d1} = 1.74320	ν _{d1} = 49.34
r ₂ = 4.6930 (非球面)	d ₂ = 2.0000		
r ₃ = 8.5950	d ₃ = 1.8000	n _{d2} = 1.80518	ν _{d2} = 25.42
r ₄ = 20.6048	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.2440 (非球面)	d ₆ = 2.0000	n _{d3} = 1.80610	ν _{d3} = 40.92
r ₇ = ∞	d ₇ = 0.7000	n _{d4} = 1.84666	ν _{d4} = 23.78
r ₈ = 5.0693	d ₈ = 0.6000		
r ₉ = 24.7066 (非球面)	d ₉ = 1.3000	n _{d5} = 1.69350	ν _{d5} = 53.21
r ₁₀ = -10.1759	d ₁₀ = 0.1500		
r ₁₁ = -266.8373	d ₁₁ = 0.7000	n _{d6} = 1.80100	ν _{d6} = 34.97
r ₁₂ = 14.0737	d ₁₂ = (可変)		
r ₁₃ = 20.4220	d ₁₃ = 1.8000	n _{d7} = 1.48749	ν _{d7} = 70.23
r ₁₄ = -14.3628	d ₁₄ = (可変)		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν _{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν _{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν _{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.2092		
r ₂₀ = ∞ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -1.1214 \times 10^{-3}$$

$$A_6 = 3.1893 \times 10^{-5}$$

$$A_8 = -4.1833 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -1.7255 \times 10^{-5}$$

$$A_6 = -4.4178 \times 10^{-5}$$

$$A_8 = 9.1087 \times 10^{-5}$$

$$A_{10} = 0.0000$$

第 9 面

$$K = 0$$

$$A_4 = -3.5926 \times 10^{-3}$$

$$A_6 = -7.1592 \times 10^{-5}$$

$$A_8 = -6.8024 \times 10^{-5}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.52199	8.69159	12.89618
F _{No}	2.6728	3.5913	4.5324
ω (°)	33.2	18.1	12.4
d ₄	13.53589	4.62823	1.50000
d ₁₂	2.53628	7.65616	12.90171
d ₁₄	0.92173	0.98067	1.00178

【 0 1 2 1 】

実施例 6

r ₁ = -115.4675	d ₁ = 0.7000	n _{d1} = 1.80610	ν_{d1} = 40.92
r ₂ = 5.0884 (非球面)	d ₂ = 2.4077		
r ₃ = 11.8048	d ₃ = 1.5055	n _{d2} = 1.84666	ν_{d2} = 23.78
r ₄ = 79.1966	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.9875 (非球面)	d ₆ = 2.2097	n _{d3} = 1.80610	ν_{d3} = 40.92
r ₇ = -92.9504	d ₇ = 0.7000	n _{d4} = 1.84666	ν_{d4} = 23.78
r ₈ = 7.0480	d ₈ = 1.7157		
r ₉ = 20.4501 (非球面)	d ₉ = 1.4488	n _{d5} = 1.69350	ν_{d5} = 53.21
r ₁₀ = -5.4179	d ₁₀ = 0.2153		
r ₁₁ = -6.0014	d ₁₁ = 1.0000	n _{d6} = 1.80100	ν_{d6} = 34.97
r ₁₂ = 56.3492	d ₁₂ = (可変)		
r ₁₃ = 12.4691	d ₁₃ = 1.6359	n _{d7} = 1.48749	ν_{d7} = 70.23
r ₁₄ = -24.0279	d ₁₄ = (可変)		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν_{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν_{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν_{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.1985		
r ₂₀ = ∞ (像面)			

非球面係数

第 2 面

$$K = 0$$

$$A_4 = -1.0638 \times 10^{-3}$$

$$A_6 = 2.1512 \times 10^{-5}$$

$$A_8 = -1.6979 \times 10^{-5}$$

$$A_{10} = 0.0000$$

第 6 面

$$K = 0$$

$$A_4 = -2.6779 \times 10^{-4}$$

$$A_6 = 1.4102 \times 10^{-6}$$

$$A_8 = -8.0728 \times 10^{-7}$$

$$A_{10} = 0.0000$$

第9面

$$K = 0$$

$$A_4 = -2.1523 \times 10^{-3}$$

$$A_6 = -8.1365 \times 10^{-6}$$

$$A_8 = -5.0480 \times 10^{-6}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.49939	8.59837	12.79887
F _{NO}	2.6057	3.4199	4.4288
ω (°)	33.2	18.4	12.5
d ₄	14.90728	4.50456	1.50000
d ₁₂	2.34564	7.26336	13.74810
d ₁₄	0.95850	1.50353	0.90000

【0122】

実施例7

r ₁ = -552.0327	d ₁ = 0.7000	n _{d1} = 1.80610	ν_{d1} = 40.92
r ₂ = 4.3477 (非球面)	d ₂ = 1.6776		
r ₃ = 8.2917	d ₃ = 1.5233	n _{d2} = 1.84666	ν_{d2} = 23.78
r ₄ = 25.4637	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.7104 (非球面)	d ₆ = 1.9721	n _{d3} = 1.80610	ν_{d3} = 40.92
r ₇ = -33.7287	d ₇ = 0.7000	n _{d4} = 1.84666	ν_{d4} = 23.78
r ₈ = 7.9668	d ₈ = 1.9478		
r ₉ = 22.3098 (非球面)	d ₉ = 1.3699	n _{d5} = 1.69350	ν_{d5} = 53.21
r ₁₀ = -5.5074	d ₁₀ = 0.1000		
r ₁₁ = -6.0325	d ₁₁ = 1.0000	n _{d6} = 1.80100	ν_{d6} = 34.97
r ₁₂ = 52.7538	d ₁₂ = (可変)		
r ₁₃ = 15.2026	d ₁₃ = 1.7414	n _{d7} = 1.48749	ν_{d7} = 70.23
r ₁₄ = -14.4840	d ₁₄ = (可変)		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν_{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν_{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν_{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.2000		
r ₂₀ = ∞ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -1.4967 \times 10^{-3}$$

$$A_6 = 1.2766 \times 10^{-6}$$

$$A_8 = -5.5780 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -3.4707 \times 10^{-4}$$

$$A_6 = 2.7502 \times 10^{-6}$$

$$A_8 = -8.5549 \times 10^{-7}$$

$$A_{10} = 0.0000$$

第9面

$$K = 0$$

$$A_4 = -2.6615 \times 10^{-3}$$

$$A_6 = -9.6885 \times 10^{-5}$$

$$A_8 = -1.1909 \times 10^{-5}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.50002	8.89986	12.79811
F_{No}	2.6022	3.5568	4.6259
ω (°)	33.1	17.8	12.6
d_4	10.91791	3.18224	1.50000
d_{12}	1.70000	7.41371	14.11791
d_{14}	0.90000	1.65812	0.90000

【0123】

実施例8

$r_1 = -34.8037$	$d_1 = 0.7000$	$n_{d1} = 1.80610$	$v_{d1} = 40.92$
$r_2 = 4.1900$ (非球面)	$d_2 = 1.1999$		
$r_3 = 8.0659$	$d_3 = 1.6447$	$n_{d2} = 1.84666$	$v_{d2} = 23.78$
$r_4 = 48.7210$	$d_4 =$ (可変)		
$r_5 = \infty$ (絞り)	$d_5 = 1.2000$		
$r_6 = 3.8631$ (非球面)	$d_6 = 1.7680$	$n_{d3} = 1.80610$	$v_{d3} = 40.92$
$r_7 = 62.8242$	$d_7 = 0.7000$	$n_{d4} = 1.84666$	$v_{d4} = 23.78$
$r_8 = 4.5969$	$d_8 = 2.3429$		
$r_9 = 13.0143$ (非球面)	$d_9 = 1.4756$	$n_{d5} = 1.69350$	$v_{d5} = 53.21$
$r_{10} = -7.3240$	$d_{10} = 0.1000$		
$r_{11} = -6.0586$	$d_{11} = 1.0000$	$n_{d6} = 1.80100$	$v_{d6} = 34.97$
$r_{12} = -25.9560$	$d_{12} =$ (可変)		
$r_{13} = 44.0311$	$d_{13} = 1.6462$	$n_{d7} = 1.48749$	$v_{d7} = 70.23$
$r_{14} = -10.9953$	$d_{14} =$ (可変)		
$r_{15} = \infty$	$d_{15} = 0.8000$	$n_{d8} = 1.51633$	$v_{d8} = 64.14$
$r_{16} = \infty$	$d_{16} = 1.5000$	$n_{d9} = 1.54771$	$v_{d9} = 62.84$
$r_{17} = \infty$	$d_{17} = 0.8000$		
$r_{18} = \infty$	$d_{18} = 0.7500$	$n_{d10} = 1.51633$	$v_{d10} = 64.14$
$r_{19} = \infty$	$d_{19} = 1.1968$		
$r_{20} = \infty$ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -2.0325 \times 10^{-3}$$

$$A_6 = -5.3892 \times 10^{-6}$$

$$A_8 = -6.1267 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -7.6210 \times 10^{-4}$$

$$A_6 = -2.6462 \times 10^{-6}$$

$$A_8 = -4.0575 \times 10^{-6}$$

$$A_{10} = -1.4214 \times 10^{-8}$$

第9面

$$K = 0$$

$$A_4 = -1.9457 \times 10^{-3}$$

$$A_6 = -9.6412 \times 10^{-5}$$

$$A_8 = 9.3922 \times 10^{-7}$$

$$A_{10} = -3.1543 \times 10^{-6}$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.49848	8.59759	12.79866
FNo	2.6659	3.7467	4.6171
ω (°)	33.2	18.5	12.7
d ₄	10.65871	4.48879	1.50000
d ₁₂	1.89640	8.96466	14.27271
d ₁₄	1.11760	0.02771	0.90000

[0124]

実施例9

r ₁ = 354.9584	d ₁ = 0.7000	n _{d1} = 1.80610	ν_{d1} = 40.92
r ₂ = 4.6698 (非球面)	d ₂ = 2.0000		
r ₃ = 9.2747	d ₃ = 1.8000	n _{d2} = 1.84666	ν_{d2} = 23.78
r ₄ = 29.2897	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.7808 (非球面)	d ₆ = 2.0000	n _{d3} = 1.80610	ν_{d3} = 40.92
r ₇ = -100.0000	d ₇ = 0.7000	n _{d4} = 1.84666	ν_{d4} = 23.78
r ₈ = 7.1229	d ₈ = 0.9250		
r ₉ = 11.1248	d ₉ = 1.3000	n _{d5} = 1.69350	ν_{d5} = 53.21
r ₁₀ = -575.7637 (非球面)	d ₁₀ = 0.1500		
r ₁₁ = 149.0119	d ₁₁ = 0.7000	n _{d6} = 1.84666	ν_{d6} = 23.78
r ₁₂ = 16.0252	d ₁₂ = (可変)		
r ₁₃ = 18.2359	d ₁₃ = 1.8000	n _{d7} = 1.48749	ν_{d7} = 70.23
r ₁₄ = -16.5835	d ₁₄ = (可変)		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν_{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν_{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν_{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.2099		
r ₂₀ = ∞ (像面)			

非球面係数

第2面

$$K = 0$$

$$A_4 = -1.1690 \times 10^{-3}$$

$$A_6 = 1.7413 \times 10^{-5}$$

$$A_8 = -3.7161 \times 10^{-6}$$

$$A_{10} = 0.0000$$

第6面

$$K = 0$$

$$A_4 = -8.5856 \times 10^{-5}$$

$$A_6 = 1.6399 \times 10^{-6}$$

$$A_8 = -4.4906 \times 10^{-8}$$

$$A_{10} = 0.0000$$

第 10 面

$$K = 0$$

$$A_4 = 3.0886 \times 10^{-3}$$

$$A_6 = 7.0935 \times 10^{-5}$$

$$A_8 = 2.3661 \times 10^{-5}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.50424	8.68935	12.89934
F _{NO}	2.6359	3.5740	4.5352
ω (°)	33.3	18.1	12.4
d ₄	13.20936	4.52377	1.50000
d ₁₂	2.53628	7.86108	13.31534
d ₁₄	0.92173	0.98683	0.99884

【0125】

実施例 10

r ₁ = 84.8334	d ₁ = 0.7000	n _{d1} = 1.74320	ν_{d1} = 49.34
r ₂ = 4.8594 (非球面)	d ₂ = 2.0000		
r ₃ = 9.0964	d ₃ = 1.8000	n _{d2} = 1.84666	ν_{d2} = 23.78
r ₄ = 18.5606	d ₄ = (可変)		
r ₅ = ∞ (絞り)	d ₅ = 1.2000		
r ₆ = 4.2563 (非球面)	d ₆ = 2.0000	n _{d3} = 1.80610	ν_{d3} = 40.92
r ₇ = 100.0000	d ₇ = 0.7000	n _{d4} = 1.84666	ν_{d4} = 23.78
r ₈ = 6.3678	d ₈ = 0.4000		
r ₉ = -34.3924	d ₉ = 1.3000	n _{d5} = 1.69350	ν_{d5} = 53.21
r ₁₀ = -8.0179 (非球面)	d ₁₀ = 0.3000		
r ₁₁ = -8.3805	d ₁₁ = 0.7000	n _{d6} = 1.84666	ν_{d6} = 23.78
r ₁₂ = -21.0856	d ₁₂ = (可変)		
r ₁₃ = 14.6488	d ₁₃ = 1.8000	n _{d7} = 1.48749	ν_{d7} = 70.23
r ₁₄ = -20.2077	d ₁₄ = (可変)		
r ₁₅ = ∞	d ₁₅ = 0.8000	n _{d8} = 1.51633	ν_{d8} = 64.14
r ₁₆ = ∞	d ₁₆ = 1.5000	n _{d9} = 1.54771	ν_{d9} = 62.84
r ₁₇ = ∞	d ₁₇ = 0.8000		
r ₁₈ = ∞	d ₁₈ = 0.7500	n _{d10} = 1.51633	ν_{d10} = 64.14
r ₁₉ = ∞	d ₁₉ = 1.2068		
r ₂₀ = ∞ (像面)			

非球面係数

第 2 面

$$K = 0$$

$$A_4 = -1.0284 \times 10^{-3}$$

$$A_6 = 3.3497 \times 10^{-5}$$

$$A_8 = -3.4598 \times 10^{-5}$$

$$A_{10} = 0.0000$$

第 6 面

$$K = 0$$

$$A_4 = -5.8749 \times 10^{-5}$$

$$A_6 = -9.9305 \times 10^{-5}$$

$$A_8 = 6.6151 \times 10^{-5}$$

$$A_{10} = 0.0000$$

第 10 面

$$K = 0$$

$$A_4 = 3.5852 \times 10^{-3}$$

$$A_6 = 2.6012 \times 10^{-4}$$

$$A_8 = 4.5257 \times 10^{-5}$$

$$A_{10} = 0.0000$$

ズームデータ (∞)

	WE	ST	TE
f (mm)	4.51247	8.69085	12.90169
F _{NO}	2.7040	3.5173	4.5477
ω (°)	33.2	18.1	12.3
d ₄	13.56120	4.06037	1.50000
d ₁₂	2.53628	6.76140	13.02411
d ₁₄	0.92173	1.69971	1.00981

【0126】以上の実施例1の無限遠物点合焦時及び被写体距離10cm合焦時の収差図をそれぞれ図11、図12に示す。これらの収差図において、(a)は広角端、(b)は中間状態、(c)は望遠端における球面収差SA、非点収差AS、歪曲収差DT、倍率色収差CCを示す。図中、“FIY”は像高を表す。

【0127】なお、上記実施例中で開示した非球面について、その面の偏倚量の基準となる基準球面の曲率半径rはその面のr_a (aは面番号)として示してある。

【0128】次に、上記各実施例における条件(1)～(5)、(7)～(17)の値、条件(6)に関するAs_{p21F}、As_{p2R}及びLの値を示す。

実施例	1	2	3	4	5
(1)	1.40795	0.89509	0.91360	1.36378	1.19446
(2)	0.50176	0.69462	0.84327	0.55884	0.52936
(3)	0.02679	0.01786	0.01786	0.02679	0.02679
(4)	0.10067	0.45293	0.48599	0.05301	0.21846
(5)	35.38000	35.38000	35.38000	44.93000	35.38000
(7)	-0.16942	0.05535	0.04515	-0.15390	-0.08862
(8)	0.28050	1.40535	1.35749	0.13534	0.68642
(9)	0.20624	0.10763	0.09287	0.18179	0.10714
(10)	-0.22380	2.21234	2.06386	0.34032	0.00000
(11)	0.20618	0.91029	0.89705	0.10983	0.39782
(12)	-0.27479	-0.23868	0.14846	-0.44068	0.17419
(13)	1.0	1.0	1.0	1.0	1.0
(14)	0.04	0.04	0.04	0.04	0.04
(15)	0.0	0.0	0.0	0.0	0.0
(16)	1.06	1.06	1.06	1.06	1.06
(17)	0.333	0.333	0.333	0.333	0.333
	(a=3.0)	(a=3.0)	(a=3.0)	(a=3.0)	(a=3.0)
As _{p21F}	-0.00086	-0.00377	-0.00393	-0.00055	-0.00159
As _{p2R}	-0.01973	-0.01290	-0.01280	-0.03454	-0.02245
L	5.6	5.6	5.6	5.6	5.6

実施例	6	7	8	9	10
(1)	1.4130	1.6913	1.1900	1.48990	1.49609
(2)	0.10050	0.08851	-0.02852	0.04735	0.03011
(3)	0.03845	0.01786	0.01786	0.02679	0.05357
(4)	0.11252	0.06773	0.26914	0.11434	0.04250
(5)	35.38000	35.38000	35.38000	46.57000	46.57000
(7)	-0.17120	-0.25687	-0.08674	-0.19676	-0.19874
(8)	0.34339	0.18764	0.87599	0.37005	0.13448
(9)	0.30638	0.34782	0.41838	0.16517	0.07143

(10)	-0.14892	-0.32727	0.20611	-0.12627	0.10616
(11)	0.22705	0.11962	0.46776	0.20849	0.07773
(12)	-0.31671	0.02420	0.60036	0.04746	-0.15948
(13)	1.0	1.0	1.0	1.0	1.0
(14)	0.04	0.04	0.04	0.04	0.04
(15)	0.0	0.0	0.0	0.0	0.0
(16)	1.06	1.06	1.06	1.06	1.06
(17)	0.333	0.333	0.333	0.333	0.333
	(a=3.0)	(a=3.0)	(a=3.0)	(a=3.0)	(a=3.0)
Asp21F	-0.00215	-0.00276	-0.00693	-0.00065	-0.00027
Asp2R	-0.01929	-0.02414	-0.01817	0.02770	0.03728
L	5.6	5.6	5.6	5.6	5.6

【0129】なお、実施例1～10のローパスフィルターLFの総厚 t_{LFF} は何れも1.500 (mm)で3枚重ねで構成している。もちろん、上述の実施例は、例えばローパスフィルターLFを1枚で構成する等、前記した構成の範囲内で種々変更可能である。

【0130】ここで、有効撮像面の対角長Lと画素間隔aについて説明しておく。図14は、撮像素子の画素配列の1例を示す図であり、画素間隔aでR (赤)、G (緑)、B (青)の画素あるいはシアン、マゼンダ、イエロー、グリーン (緑)の4色の画素 (図14)がモザイク状に配されている。有効撮像面は撮影した映像の再生 (パソコン上での表示、プリンターによる印刷等)に用いる撮像素子上の光電変換面内における領域を意味する。図中に示す有効撮像面は、光学系の性能 (光学系の性能が確保し得るイメージサークル)に合わせて、撮像素子の全光電変換面よりも狭い領域に設定されている。有効撮像面の対角長Lは、この有効撮像面の対角長である。なお、映像の再生に用いる撮像範囲を種々変更可能としてよいが、そのような機能を有する撮像装置に本発明のズームレンズを用いる際は、その有効撮像面の対角

長Lが変化する。そのような場合は、本発明における有効撮像面の対角長Lは、Lのとり得る範囲における最大値とする。

【0131】また、赤外カット手段については、赤外カット吸収フィルターIFと赤外シャープカットコートとがあり、赤外カット吸収フィルターIFはガラス中に赤外吸収体が含有される場合で、赤外シャープカットコートは吸収でなく反射によるカットである。したがって、前記したように、この赤外カット吸収フィルターIFを除去して、ローパスフィルターLFに直接赤外シャープカットコートを施してもよいし、ダミー透明平板上に施してもよい。

【0132】この場合の近赤外シャープカットコートは、波長600nmでの透過率が80%以上、波長700nmでの透過率が10%以下となるように構成することが望ましい。具体的には、例えば次のような27層の層構成からなる多層膜である。ただし、設計波長は780nmである。

【0133】

基 板	材 質	物理的膜厚 (nm)	$\lambda/4$
第1層	Al_2O_3	58.96	0.50
第2層	TiO_2	84.19	1.00
第3層	SiO_2	134.14	1.00
第4層	TiO_2	84.19	1.00
第5層	SiO_2	134.14	1.00
第6層	TiO_2	84.19	1.00
第7層	SiO_2	134.14	1.00
第8層	TiO_2	84.19	1.00
第9層	SiO_2	134.14	1.00
第10層	TiO_2	84.19	1.00
第11層	SiO_2	134.14	1.00
第12層	TiO_2	84.19	1.00
第13層	SiO_2	134.14	1.00
第14層	TiO_2	84.19	1.00
第15層	SiO_2	178.41	1.33

第16層	TiO ₂	101.03	1.21
第17層	SiO ₂	167.67	1.25
第18層	TiO ₂	96.82	1.15
第19層	SiO ₂	147.55	1.05
第20層	TiO ₂	84.19	1.00
第21層	SiO ₂	160.97	1.20
第22層	TiO ₂	84.19	1.00
第23層	SiO ₂	154.26	1.15
第24層	TiO ₂	95.13	1.13
第25層	SiO ₂	160.97	1.20
第26層	TiO ₂	99.34	1.18
第27層	SiO ₂	87.19	0.65

空 気

【0134】上記の近赤外シャープカットコートの透過率特性は図15に示す通りである。

【0135】また、ローパスフィルターLFの射出面側には、図16に示すような短波長域の色の透過を低減する色フィルターを設けるか若しくはコーティングを行うことで、より一層電子画像の色再現性を高めている。

【0136】具体的には、このフィルター若しくはコーティングにより、波長400nm～700nmで透過率が最も高い波長の透過率に対する420nmの波長の透過率の比が15%以上であり、その最も高い波長の透過率に対する400nmの波長の透過率の比が6%以下であることが好ましい。

【0137】それにより、人間の目の色に対する認識と、撮像及び再生される画像の色とのずれを低減させることができる。言い換えると、人間の視覚では認識され難い短波長側の色が、人間の目で容易に認識されることによる画像の劣化を防止することができる。

【0138】上記の400nmの波長の透過率の比が6%を越えると、人間の目では認識され難い単波長域が認識し得る波長に再生されてしまい、逆に、上記の420nmの波長の透過率の比が15%よりも小さいと、人間の認識し得る波長域の再生が低くなり、色のバランスが悪くなる。

【0139】このような波長を制限する手段は、補色モザイクフィルターを用いた撮像系においてより効果を奏するものである。

【0140】上記各実施例では、図16に示すように、波長400nmにおける透過率を0%、420nmにおける透過率を90%、440nmにて透過率のピーク100%となるコーティングとしている。

【0141】前記した近赤外シャープカットコートとの作用の掛け合わせにより、波長450nmの透過率99%をピークとして、400nmにおける透過率を0%、420nmにおける透過率を80%、600nmにおける透過率を82%、700nmにおける透過率を2%としている。それにより、より忠実な色再現を行って

る。

【0142】また、ローパスフィルターLFは、像面上投影時の方位角度が水平(=0°)と±45°方向にそれぞれ結晶軸を有する3種類のフィルターを光軸方向に重ねて使用しており、それぞれについて、水平にaμm、±45°方向にそれぞれSQRT(1/2)×aだけずらすことで、モアレ抑制を行っている。ここで、SQRTは前記のようにスクエアルートであり平方根を意味する。

【0143】また、CCDの撮像面I上には、図17に示す通り、シアン、マゼンダ、イエロー、グリーン

(緑)の4色の色フィルターを撮像素素に対応してモザイク状に設けた補色モザイクフィルターを設けている。これら4種類の色フィルターは、それぞれが略同じ数になるように、かつ、隣り合う画素が同じ種類の色フィルターに対応しないようにモザイク状に配置されている。それにより、より忠実な色再現が可能となる。

【0144】補色モザイクフィルターは、具体的には、図17に示すように少なくとも4種類の色フィルターから構成され、その4種類の色フィルターの特性は以下の通りであることが好ましい。

【0145】グリーンの色フィルターGは波長G_Pに分光強度のピークを有し、イエローの色フィルターYは波長Y_Pに分光強度のピークを有し、シアンの色フィルターCは波長C_Pに分光強度のピークを有し、マゼンダの色フィルターMは波長M_{P1}とM_{P2}にピークを有し、以下の条件を満足する。

【0146】510nm<G_P<540nm

5nm<Y_P-G_P<35nm

-100nm<C_P-G_P<-5nm

430nm<M_{P1}<480nm

580nm<M_{P2}<640nm

さらに、グリーン、イエロー、シアンの色フィルターはそれぞれの分光強度のピークに対して波長530nmでは80%以上の強度を有し、マゼンダの色フィルターはその分光強度のピークに対して波長530nmでは10%から50%の強度を有することが、色再現性を高める

上でより好ましい。

【0147】上記各実施例におけるそれぞれの波長特性の一例を図18に示す。グリーンの色フィルターGは525nmに分光強度のピークを有している。イエローの色フィルターYは555nmに分光強度のピークを有している。シアンの色フィルターCは510nmに分光強度のピークを有している。マゼンダの色フィルターMは445nmと620nmにピークを有している。また、530nmにおける各色フィルターは、それぞれの分光強度のピークに対して、Gは99%、Yは95%、Cは97%、Mは38%としている。

【0148】このような補色フィルターの場合、図示しないコントローラー（若しくは、デジタルカメラに用いられるコントローラー）で、電氣的に次のような信号処理を行い、

輝度信号

$$Y = |G + M + Y_c + C| \times 1/4$$

色信号

$$R - Y = | (M + Y_c) - (G + C) |$$

$$B - Y = | (M + C) - (G + Y_c) |$$

の信号処理を経てR（赤）、G（緑）、B（青）の信号に変換される。

【0149】ところで、上記した近赤外シャープカットフィルターの配置位置は、光路上のどの位置であってもよい。また、ローパスフィルターLFの枚数も前記した通り2枚でも1枚でも構わない。

【0150】さて、以上のような本発明の電子撮像装置は、ズームレンズで物体像を形成しその像をCCD等の電子撮像素子に受光させて撮影を行う撮影装置、とりわけデジタルカメラやビデオカメラ、情報処理装置の例であるパソコン、電話、特に持ち運びに便利な携帯電話等に用いることができる。以下に、その実施形態を例示する。

【0151】図19～図21は、本発明によるズームレンズをデジタルカメラの撮影光学系41に組み込んだ構成の概念図を示す。図19はデジタルカメラ40の外観を示す前方斜視図、図20は同後方斜視図、図21はデジタルカメラ40の構成を示す断面図である。デジタルカメラ40は、この例の場合、撮影用光路42を有する撮影光学系41、ファインダー用光路44を有するファインダー光学系43、シャッター45、フラッシュ46、液晶表示モニター47等を含み、カメラ40の上部に配置されたシャッター45を押圧すると、それに連動して撮影光学系41、例えば実施例1のズームレンズを通して撮影が行われる。撮影光学系41によって形成された物体像が、近赤外カットコートをダミー透明平板上に施してなる赤外カット吸収フィルターIF、光学的ローパスフィルターLFを介してCCD49の撮像面上に形成される。このCCD49で受光された物体像は、処理手段51を介し、電子画像としてカメラ背面に設けら

れた液晶表示モニター47に表示される。また、この処理手段51には記録手段52が接続され、撮影された電子画像を記録することもできる。なお、この記録手段52は処理手段51と別体に設けてもよいし、フロッピー（登録商標）ディスクやメモリーカード、MO等により電的に記録書込を行うように構成してもよい。また、CCD49に代わって銀塩フィルムを配置した銀塩カメラとして構成してもよい。

【0152】さらに、ファインダー用光路44上にはファインダー用対物光学系53が配置してある。このファインダー用対物光学系53によって形成された物体像は、像正立部材であるポロプリズム55の視野枠57上に形成される。このポロプリズム55の後方には、正立正像にされた像を観察者眼球Eに導く接眼光学系59が配置されている。なお、撮影光学系41及びファインダー用対物光学系53の入射側、接眼光学系59の射出側にそれぞれカバー部材50が配置されている。

【0153】このように構成されたデジタルカメラ40は、撮影光学系41が広画角で高変倍比であり、収差が良好で、明るく、フィルター等が配置できるバックフォーカスの大きなズームレンズであるので、高性能・低コスト化が実現できる。

【0154】なお、図21の例では、カバー部材50として平行平板を配置しているが、パワーを持ったレンズを用いてもよい。

【0155】以上の本発明のズームレンズ及びそれを有する電子撮像装置は例えば次のように構成することができる。

【0156】〔1〕 物体側より順に、負の屈折力を有する第1レンズ群と、正の屈折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件（1）を満足することを特徴とするズームレンズ。

【0157】

$$(1) \quad 0.6 < R_{22R} / R_{21F} < 2.2$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面、第2レンズ群の負レンズL22の像側の面の光軸上の曲率半径である。

【0158】〔2〕 像側に配される電子撮像素子と一体化されたことを特徴とする上記1記載ズームレンズ。

【0159】〔3〕 電子撮像素子の撮像面側に配されるズームレンズにおいて、前記ズームレンズは、物体側より順に、負の屈折力を有する第1レンズ群と、正の屈

折力を有する第2レンズ群と、正の屈折力を有する第3レンズ群よりなり、無限遠物点合焦時における広角端から望遠端への変倍に際して、前記第2レンズ群が物体側へのみ移動し、前記第3レンズ群が第2レンズ群との間隔を変化させつつ移動し、前記第2レンズ群は、物体側から順に、正レンズL21、負レンズL22、正レンズL23、負レンズL24にて構成され、前記第2レンズ群中の正レンズL23又は負レンズL24の少なくとも何れかのレンズは非球面を有し、かつ、以下の条件

(2)、(3)、(4)を満足することを特徴とするズームレンズ。

【0160】

$$(2) \quad 0 < (C_{24F} - C_{23R}) \cdot L < 1.6$$

$$(3) \quad 0.01 < d_{23}/L < 0.2$$

$$(4) \quad -0.4 < L/f_{2R} < 0.8$$

ただし、 $C_{23R} = 1/R_{23R}$ 、 $C_{24F} = 1/R_{24F}$ であり、ここで、 R_{23R} 、 R_{24F} はそれぞれ第2レンズ群の正レンズL23の像側の面、第2レンズ群の負レンズL24の物体側の面の光軸上の曲率半径、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)、 d_{23} は第2レンズ群の正レンズL23と負レンズL24との光軸上の空気間隔、 f_{2R} は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【0161】〔4〕像側に配される電子撮像素子と一体化され、かつ、以下の条件(2)、(3)、(4)を満足することを特徴とする上記1記載のズームレンズ。

【0162】

$$(2) \quad 0 < (C_{24F} - C_{23R}) \cdot L < 1.6$$

$$(6) \quad 7.5 \times 10^{-3} \cdot L > |Asp2R| > |Asp21F|$$

ただし、 $Asp21F$ 、 $Asp2R$ はそれぞれ正レンズL21の物体側の面、正レンズL23又は負レンズL24の面の光軸上での曲率半径を有する球面に対し、光軸からの高さが0.3Lでの非球面偏倚量、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)であり、正レンズL21の物体側面が球面の場合は非球面偏倚量 $Asp21F$ を0と

$$(7) \quad -0.5 < (R_{21F} - R_{22R}) / (R_{21F} + R_{22R}) < 0.3$$

ただし、 R_{21F} 、 R_{22R} はそれぞれ第2レンズ群の正レンズL21の物体側の面と負レンズL22の像側の面の光軸上の曲率半径である。

【0170】〔9〕以下の条件(8)及び(9)を満足することを特徴とする上記2から8の何れか1項記載のズームレンズ。

$$【0171】(8) \quad -1 < f_s / f_{2R} < 1.6$$

$$(9) \quad 0.02 < d_{22}/L < 0.5$$

ただし、 f_{2R} と f_s はそれぞれ第2レンズ群の正レンズL23と負レンズL24との合成焦点距離と第3レンズ群の焦点距離、 d_{22} は第2レンズ群の負レンズL22の像側面と正レンズL23の物体側面との間隔、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)である。

$$(3) \quad 0.01 < d_{23}/L < 0.2$$

$$(4) \quad -0.4 < L/f_{2R} < 0.8$$

ただし、 $C_{23R} = 1/R_{23R}$ 、 $C_{24F} = 1/R_{24F}$ であり、ここで、 R_{23R} 、 R_{24F} はそれぞれ第2レンズ群の正レンズL23の像側の面、第2レンズ群の負レンズL24の物体側の面の光軸上の曲率半径、Lは撮像素子の有効撮像領域(略矩形)の対角長(mm)、 d_{23} は第2レンズ群の正レンズL23と負レンズL24との光軸上の空気間隔、 f_{2R} は第2レンズ群の正レンズL23と負レンズL24との合成焦点距離である。

【0163】〔5〕前記第2レンズ群の正レンズL21と負レンズL22とが接合されていることを特徴とする上記2から4の何れか1項記載のズームレンズ。

【0164】〔6〕前記第2レンズ群が以下の条件

(5)を満足することを特徴とする上記2から5の何れか1項記載のズームレンズ。

【0165】

$$(5) \quad 2.5 < v_{21} - v_{22} + v_{23} - v_{24} < 5.5$$

ただし、 v_{21} 、 v_{22} 、 v_{23} 、 v_{24} はそれぞれ第2レンズ群の正レンズL21、負レンズL22、正レンズL23、負レンズL24の媒質のアッペ数(d線基準)である。

【0166】〔7〕前記第2レンズ群における正レンズL23又は負レンズL24の少なくとも何れかに配された前記非球面の少なくとも何れかが以下の条件(6)を満足することを特徴とする上記2から6の何れか1項記載のズームレンズ。

【0167】

する。

【0168】〔8〕以下の条件(7)を満足することを特徴とする上記2から7の何れか1項記載のズームレンズ。

【0169】

【0172】〔10〕以下の条件(10)を満足する上記1乃至9の何れか1項に記載のズームレンズ。

$$【0173】(10) \quad -1 < f_{2F}/R_{21R} < 2.5$$

ただし、 R_{21R} は第2レンズ群の正レンズL21の像側の面の曲率半径、 f_{2F} は第2レンズ群の正レンズL21と負レンズL22との合成焦点距離である。

【0174】〔11〕広角端から望遠端に変倍する際、前記第3レンズ群は像側に凸の軌跡で移動することを特徴とする上記1から10の何れか1項記載のズームレンズ。

【0175】〔12〕前記第3レンズ群を光軸に沿って移動することにより合焦することを特徴とする上記1から11の何れか1項記載のズームレンズ。

【0176】〔13〕広角端半面角 ω_w が 2.7° から

42°の範囲にあることを特徴とする上記1から12の何れか1項記載のズームレンズ。

【0177】〔14〕 上記1から13の何れか1項記載のズームレンズを備えたことを特徴とする電子撮像装置。

【0178】

【発明の効果】本発明により、沈胴厚が薄く収納性に優れ、かつ、高倍率でリアフォーカスにおいても結像性能の優れたズームレンズを得ることができ、ビデオカメラやデジタルカメラの徹底的薄型化を図ることが可能となる。

【図面の簡単な説明】

【図1】本発明の電子撮像装置に用いられるズームレンズの実施例1の無限遠物点合焦時の広角端(a)、中間状態(b)、望遠端(c)でのレンズ断面図である。

【図2】実施例2のズームレンズの図1と同様のレンズ断面図である。

【図3】実施例3のズームレンズの図1と同様のレンズ断面図である。

【図4】実施例4のズームレンズの図1と同様のレンズ断面図である。

【図5】実施例5のズームレンズの図1と同様のレンズ断面図である。

【図6】実施例6のズームレンズの図1と同様のレンズ断面図である。

【図7】実施例7のズームレンズの図1と同様のレンズ断面図である。

【図8】実施例8のズームレンズの図1と同様のレンズ断面図である。

【図9】実施例9のズームレンズの図1と同様のレンズ断面図である。

【図10】実施例10のズームレンズの図1と同様のレンズ断面図である。

【図11】実施例1の無限遠物点合焦時の収差図である。

【図12】実施例1の被写体距離10cm合焦時の収差図である。

【図13】本発明における非球面偏倚量の定義を説明するための図である。

【図14】電子撮像素子にて撮影を行う場合の有効撮像

面の対角長について説明するための図である。

【図15】近赤外シャープカットコートの一例の透過率特性を示す図である。

【図16】ローパスフィルターの射出面側に設ける色フィルターの一例の透過率特性を示す図である。

【図17】補色モザイクフィルターの色フィルター配置を示す図である。

【図18】補色モザイクフィルターの波長特性の一例を示す図である。

【図19】本発明によるズームレンズを組み込んだデジタルカメラの外観を示す前方斜視図である。

【図20】図19のデジタルカメラの後方斜視図である。

【図21】図19のデジタルカメラの断面図である。

【符号の説明】

G1…第1レンズ群

G2…第2レンズ群

G3…第3レンズ群

S…開口絞り

IF…赤外カット吸収フィルター

LF…ローパスフィルター

CG…カバーガラス

I…像面

E…観察者眼球

40…デジタルカメラ

41…撮影光学系

42…撮影用光路

43…ファインダー光学系

44…ファインダー用光路

45…シャッター

46…フラッシュ

47…液晶表示モニター

49…CCD

50…カバー部材

51…処理手段

52…記録手段

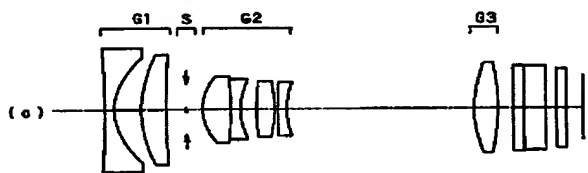
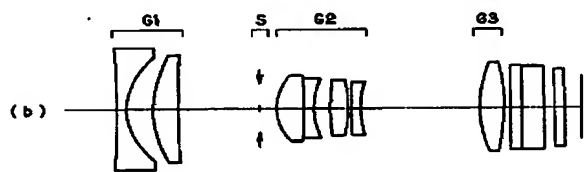
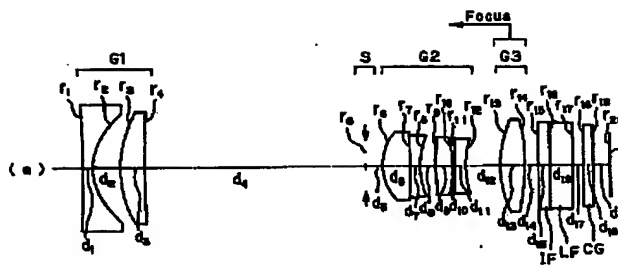
53…ファインダー用対物光学系

55…ポロプリズム

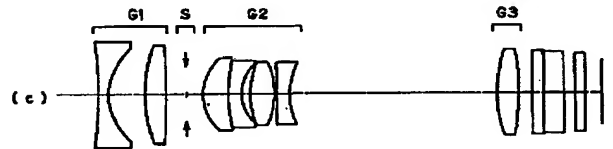
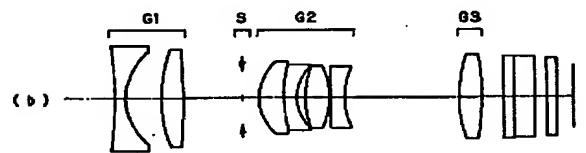
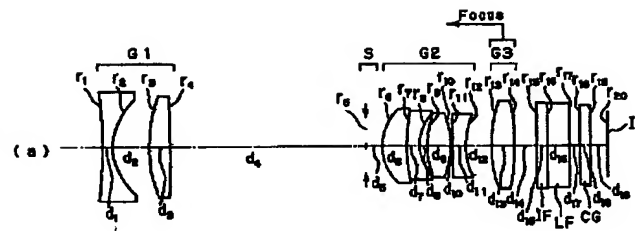
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59…接眼光学系

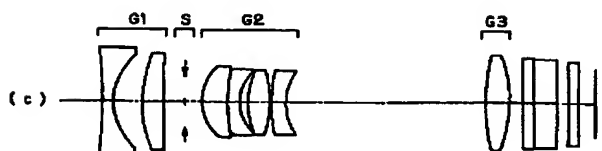
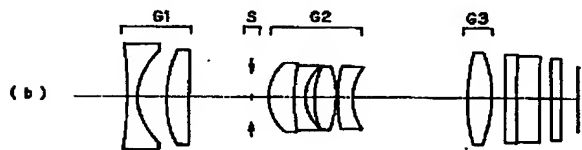
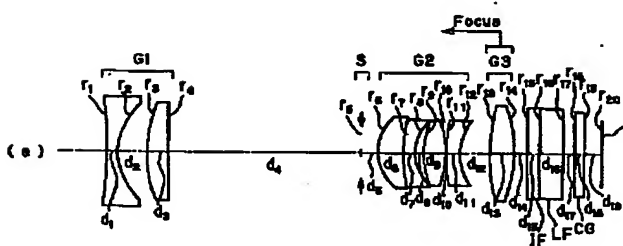
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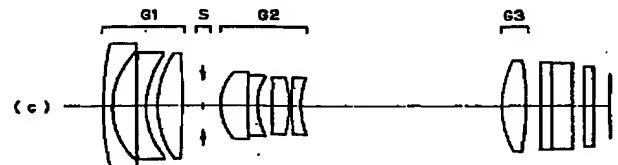
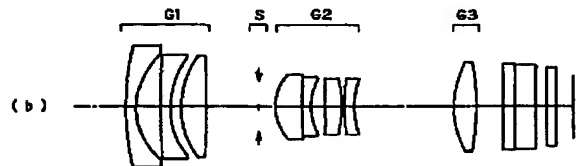
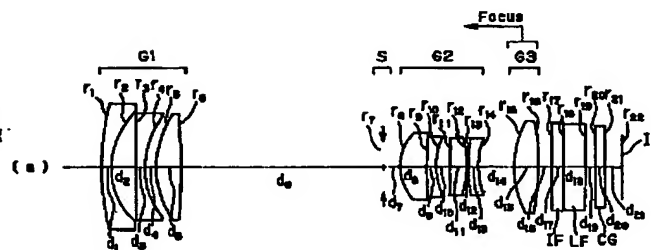
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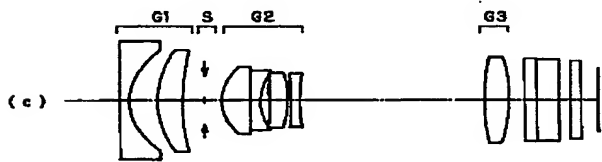
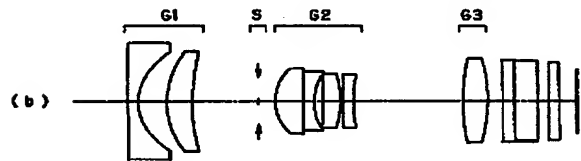
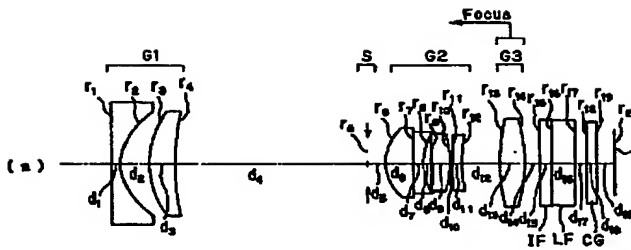
【図 3】



【図 4】

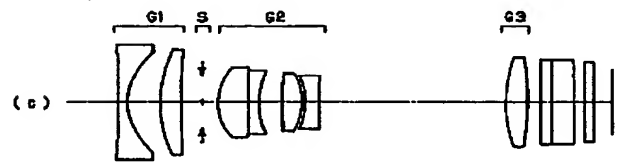
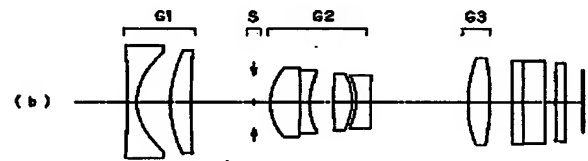
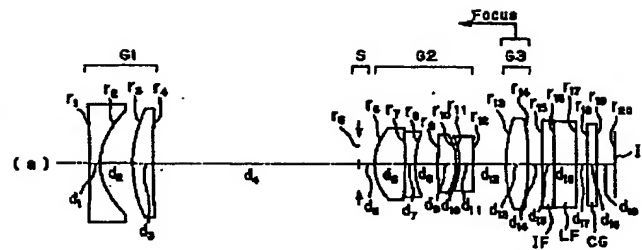


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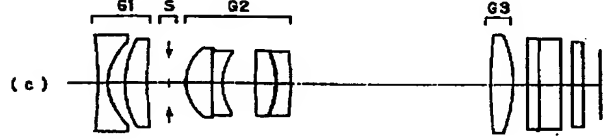
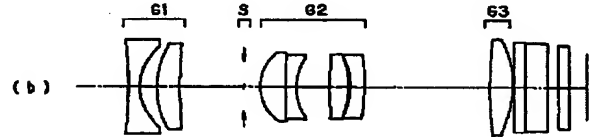
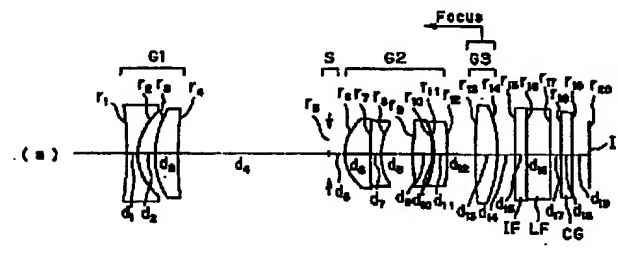
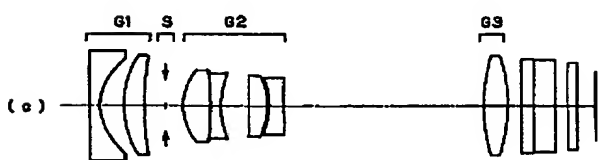
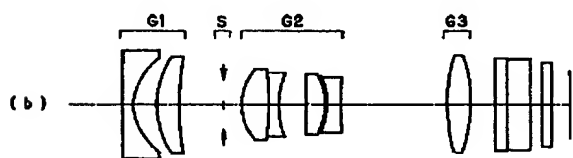
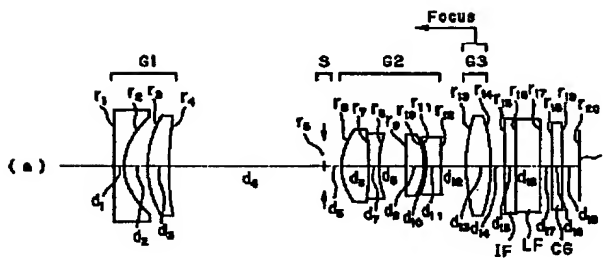


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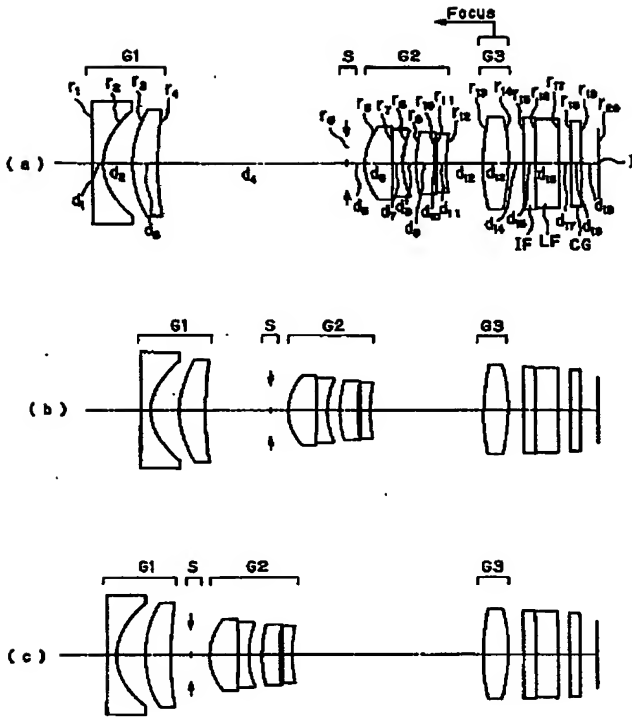
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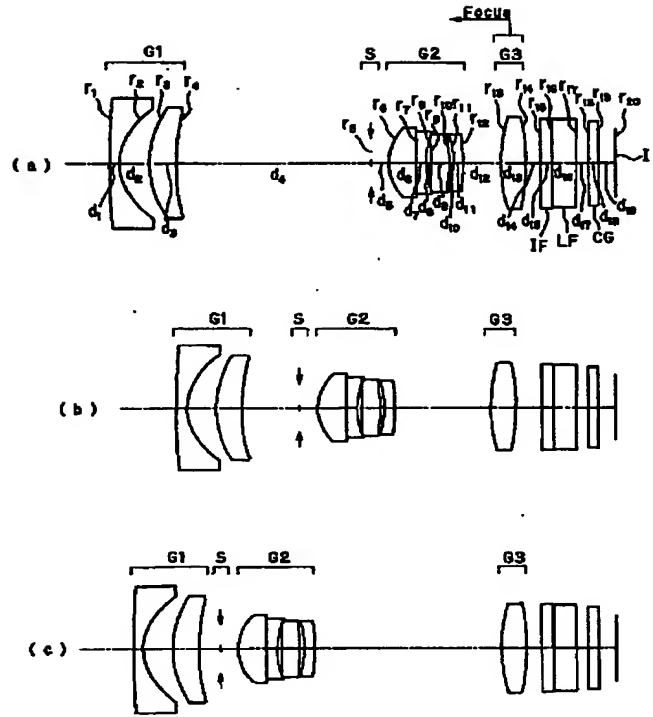
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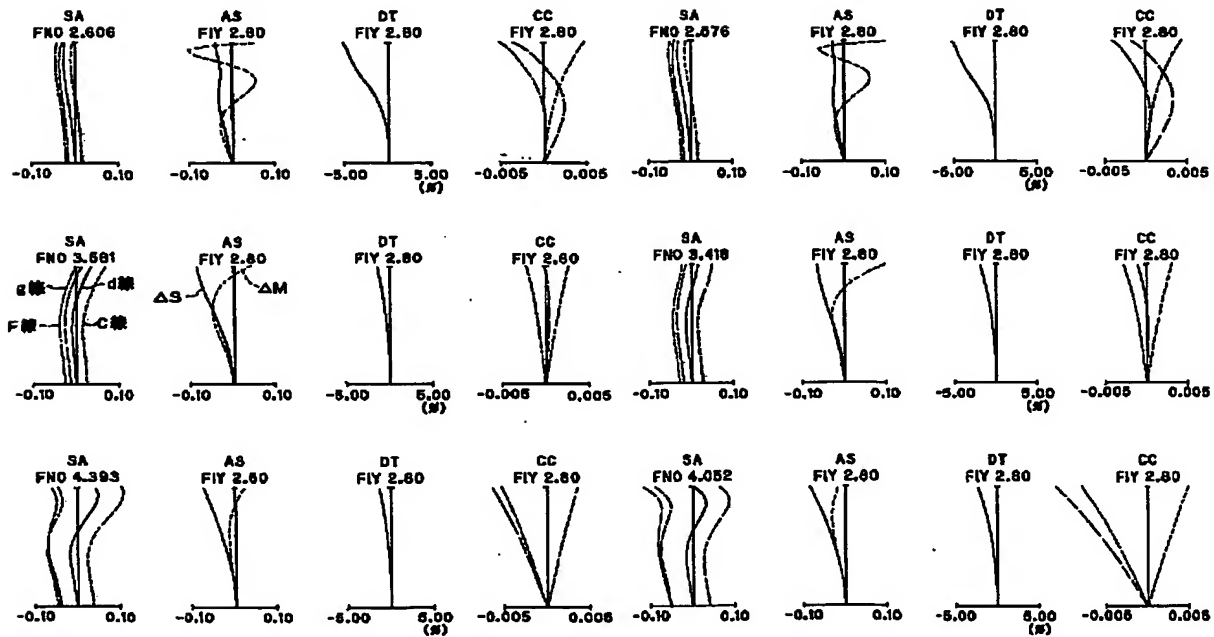
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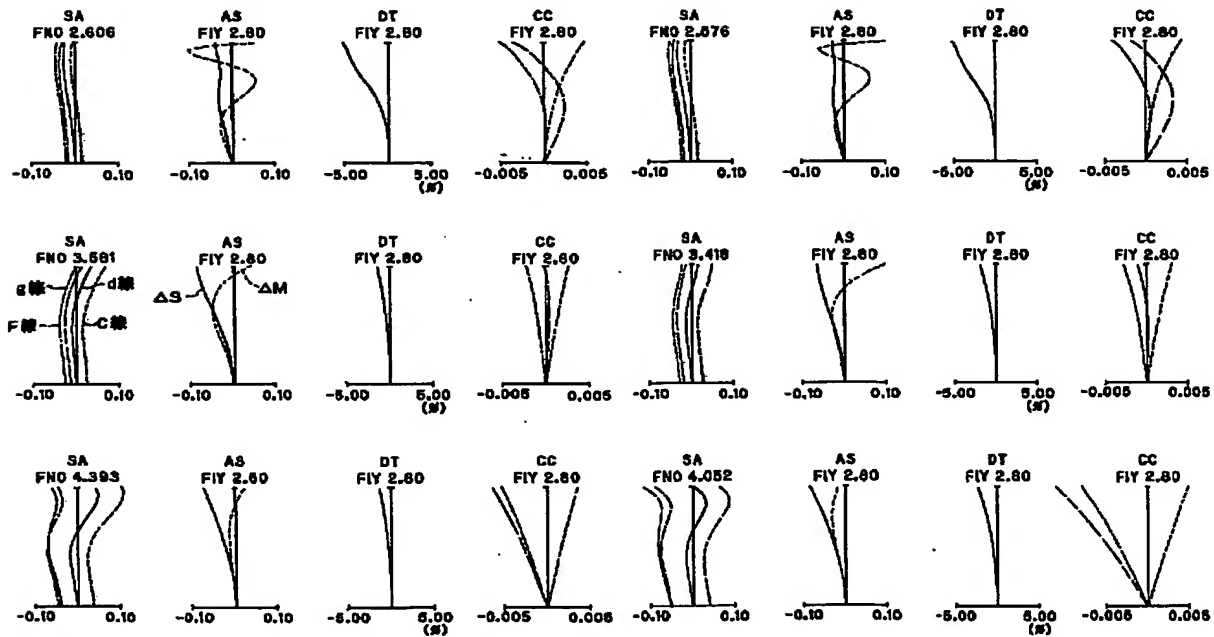
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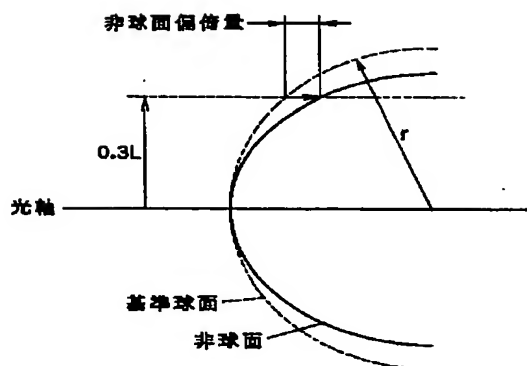
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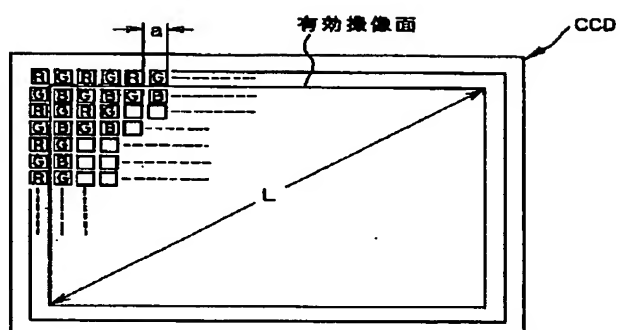
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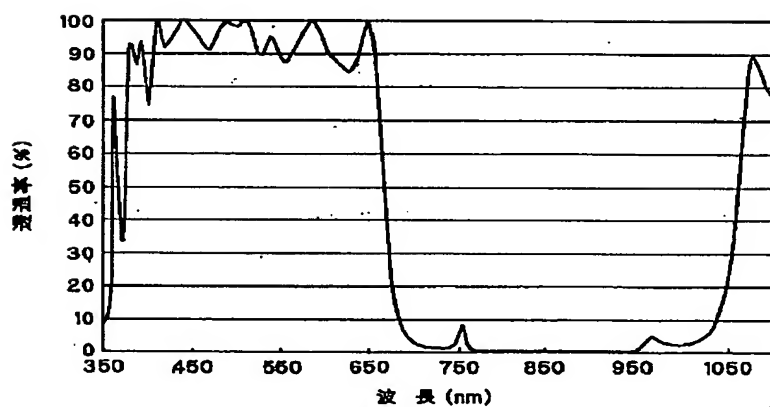
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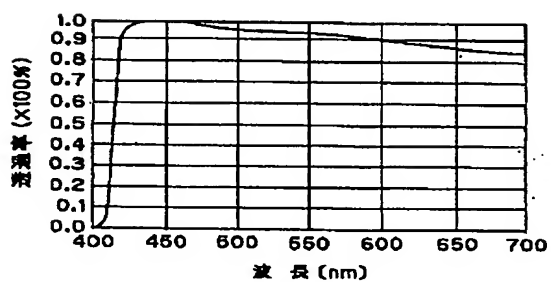
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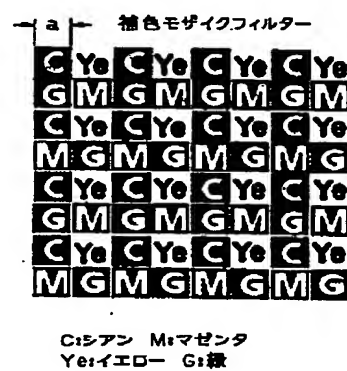
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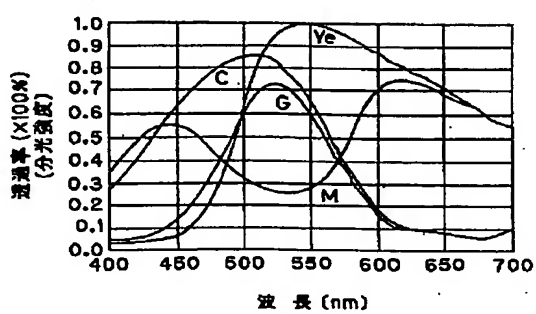
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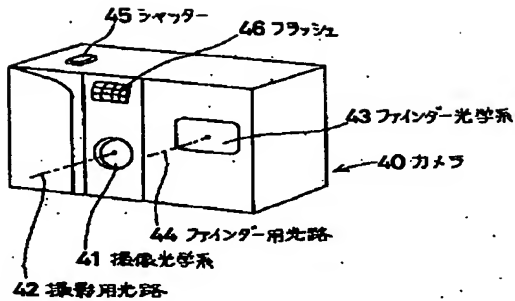
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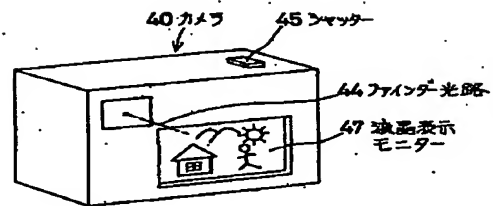
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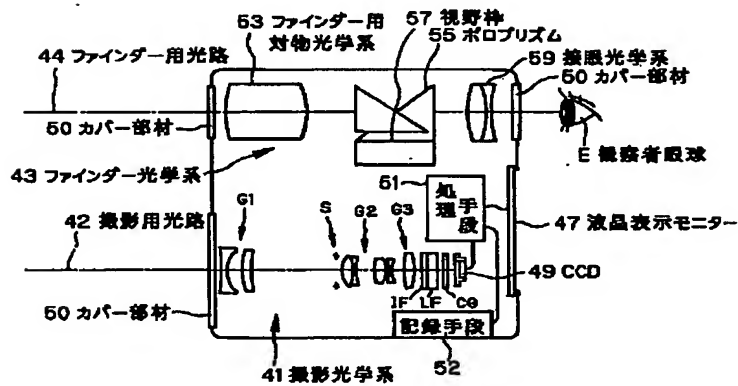
【図 19】



【図 20】



【図 21】



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